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THE ELASTIC ARCH.

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The subject of this paper is the theory of the graphical method used in connection with the design and computation of the elastic arch. The treatment is not intended to be complete but is directed specially to difficulties which have been brought to my attention by some of our graduates engaged in the design of reinforced concrete arches.

The method is originally due to Professor H. T. Eddy, now of the University of Minnesota, who published his results between 1876 and 1878. Professor Wm. Cain of the University of North Carolina was also one of the early contributors to the subject.

As a basis for the graphical method the general treatment of the arch will be first considered.

The arch is statically indeterminate, and in all treatments the three statical equations require to be supplemented by three others. On the assumption that the arch is inelastic the requisite equations are obtained by, in effect, the more or less arbitrary assumption of the positions of the centres of pressure at three cross-sections, e.g., the springing planes and the section at the apex. If on the other hand Young's modulus for the material be known, the conditions of elasticity and the methods of fixing the ends will furnish the three necessary conditions.

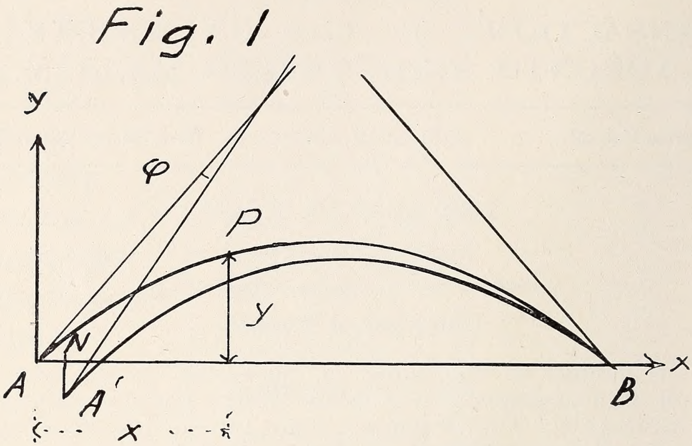
The Elastic Curved Beam.

The following theorems respecting the elastic curved beam will be stated without proof. (See Fig. 1.)

Let $A\ B$ represent the axis of the curved beam when under a given loading, $A'\ B$ the form of the axis when unstressed. Let the two curves be made to coincide in position and direction at the end B then at the ends A and A' the curves will in general differ both in position and direction.

Assume as rectangular axes of reference ABx and Ay and

let ϕ denote the angle between the directions of the tangents at A and A'. Let $AN = x'$, $NA' = y'$ be the co-ordinates of A', then it may be shown that



$$1.\quad \phi = \int^{B} \frac{M}{EI}\, ds; \qquad 2.\quad x' = \int_{A}^{B} \frac{My}{EI}\, ds; \qquad 3.\quad y' = -\int_{A}^{B} \frac{Mx}{EI}\, ds\,;$$

where x and y are the coordinates of P the current point on the curve AB, s the distance along the curve from A to P, M the bending moment at the cross-section at P, I the moment of inertia of the cross-section at P and E Young's modulus for the material of the beam. It is assumed that x' and y' are small compared with the greatest values of x and y respectively, and the lengths of AB and $A'B$ are considered equal.

The Elastic Arch with Fixed Ends.

It will be sufficient for the purpose of this paper to consider only the above arch. The loading will be assumed vertical and the form of the arch symmetrical with regard to a vertical through the apex.

In the case of a composite material such as reinforced concrete, EI will represent the composite expression $E_1\ (I_1 + nI_2)$.

The axis of the arch (often termed the neutral line) is the locus of the centres of gravity of the cross-sections of the arch if the material is homogeneous; in the case of reinforced concrete the cross-section of the steel is replaced by its concrete equivalent for the purpose of determining the centre of gravity. The axis of the arch and the cross-sections are at right angles to each other.

A bending moment M will be considered positive when it tends to make the arch concave upwards.

It is evident that in the case of the arch with fixed ends

1. $\phi = 0$; 2. $x' = 0$; 3. $y' = 0$.

Thus in this arch the following conditions hold, viz:

$$1.\ \int_A^B \frac{M}{EI}\, ds = 0; \quad 2.\ \int_A^B \frac{My}{EI}\, ds = 0; \quad 3.\ \int_A^B \frac{Mx}{EI}\, ds = 0;$$

When the various quantities are not expressible as functions of x as is usually the case, the indicated integration must be replaced by graphical summation. In doing this the general principle involved is to make the subdivisions δs of the axis so short that the values of x, y, M, E and I corresponding to the middle points of the subdivisions may be used in the summations without producing serious error. The subdivision of the arch is thus more or less a matter of judgment. It should be founded on comparisons between the results of computations made with longer and shorter subdivisions.

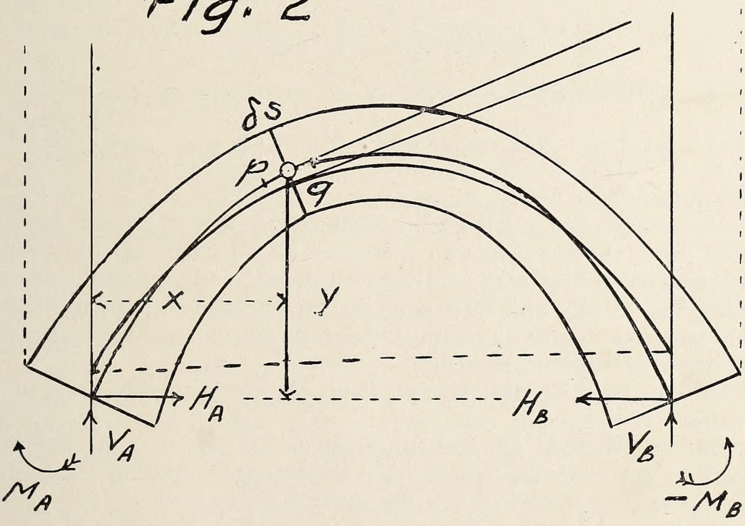
Subject to these considerations the following method of subdivision is sometimes used. The axis is divided by trial into subdivisions for which $\frac{\delta s}{EI}$ is constant or, if E is constant throughout the arch, for which $\frac{\delta s}{I}$ is constant.

The three conditions above found will then reduce to

1. $\Sigma M = 0$; 2. $\Sigma My = 0$; 3. $\Sigma Mx = 0$.

omitting for the sake of brevity the limit symbols A and B.

Fig. 2



It follows at once from these equations that the values of M throughout the arch cannot all have the same sign.

Fig. 2 is a diagram of the arch showing a type subdivision δs, the coordinates x and y of its centre point, the supporting forces and couples V_a, H_a and M_a at the end A and V_b, H_b and $-M_b$ at the end B; the loading is not shown.

The bending moment M corresponding to any subdivision δs of the axis, that is the bending moment at the cross-section of the arch having its centre of gravity at the point x, y, may be considered as arising from the algebraic addition of three bending moments M', M'', M''' defined as follows:

M' is the bending moment due to the loading (see remarks) computed on the supposition that the arch is supported by vertical forces V'_a and V'_b as in the case of the freely supported horizontal beam.

M'' is due to the bending moments M_a and M_b at the end cross-sections. It is computed by assuming the arch to be maintained in equilibrium by fixing couples M_a and $-M_b$ at the ends together with a third couple composed of equal and opposite vertical forces V''_a, V''_b acting at A and B respectively.

M''' is due to the horizontal thrust H of the abutments.

From the conditions of equilibrium defining M'' and M''' it may be easily shown that

$$M'' = M_a + \frac{M_b - M_a}{l} x \text{ where } l \text{ is the span } AB.$$

also $M''' = -Hy$ assuming H to be thrust and positive.

$$\text{Thus } M = M' + M'' + M''' = M' + M_a + \frac{M_b - M_a}{l} x - Hy.$$

Then we have, if n denote the number of subdivisions δs of the axis,

$$\text{1. } \Sigma M = \Sigma M' + nM_a + \frac{M_b - M_a}{l} \Sigma x - H\Sigma y = 0$$

$$\text{2. } \Sigma My = \Sigma M'y + M_a\Sigma y + \frac{M_b - M_a}{l} \Sigma xy - H\Sigma y^2 = 0$$

$$\text{3. } \Sigma Mx = \Sigma M'x + M_a\Sigma x + \frac{M_b - M_a}{l} \Sigma x^2 - H\Sigma xy = 0$$

the summations being taken from A to B.

Now $\Sigma M'$, $\Sigma M'y$, $\Sigma M'x$ and Σx, Σy, Σx^2, Σxy, Σy^2 may be computed from the loading and from the coordinates of the n points x, y, taken on the axis. Hence the above three equations will determine M_a, M_b and H to any degree of approximation desired. The approximation becomes closer as the lengths of the subdivisions are taken smaller.

M can now be determined from its equation for each of the n values of x.

H will denote an abutment thrust if positive, a tension if negative, so that the horizontal abutment reactions H_a and H_b become determined in both magnitude and sense.

Since the bending moment M_a and M_b are known the fixing couples M_a and $-M_b$ are determined.

NOTE—Lower case subscript letters in the text represent corresponding upper case letters in the diagrams.

Finally, the vertical abutment reactions V_a and V_b are determined from the equation of vertical resolved parts of the external forces and the equation of moments.

The positive senses adopted will be: For forces, upwards, to the right and clockwise; for stresses, thrust, shear lengthening the diagonal in a vertical rectangle from upper lefthand corner, bending producing concavity upwards.

On computing V'_a, V'_b and V''_a, V''_b from their definitions it will be found that

$$V_a = V'_a + V''_a;\ V_b = V'_b + V''_b$$

The thrusts and shears at any cross-section of the arch may now be determined.

H having been determined we may write $M'' = Hy''$, $M' = Hy'$, also $M''' = -Hy$, thus $M = H\ (y'' + y' - y)$ and the three end conditions may be written:

1. $\Sigma\ (y'' + y' - y) \qquad = 0$
2. $\Sigma\ (y'' + y' - y)\ y \qquad = 0$
3. $\Sigma\ (y'' + y' - y)\ x \qquad = 0$
4. Where $y'' = \dfrac{M''}{H} = \dfrac{M_a}{H} + \dfrac{\dfrac{M_b}{H} - \dfrac{M_a}{H}}{l}\ x$
5. and $y' = \dfrac{M'}{H}$

a result which will be used in the explanation of the graphical method.

This completes the resumé of the general method of computing the elastic arch with fixed ends.

Graphical Computation.

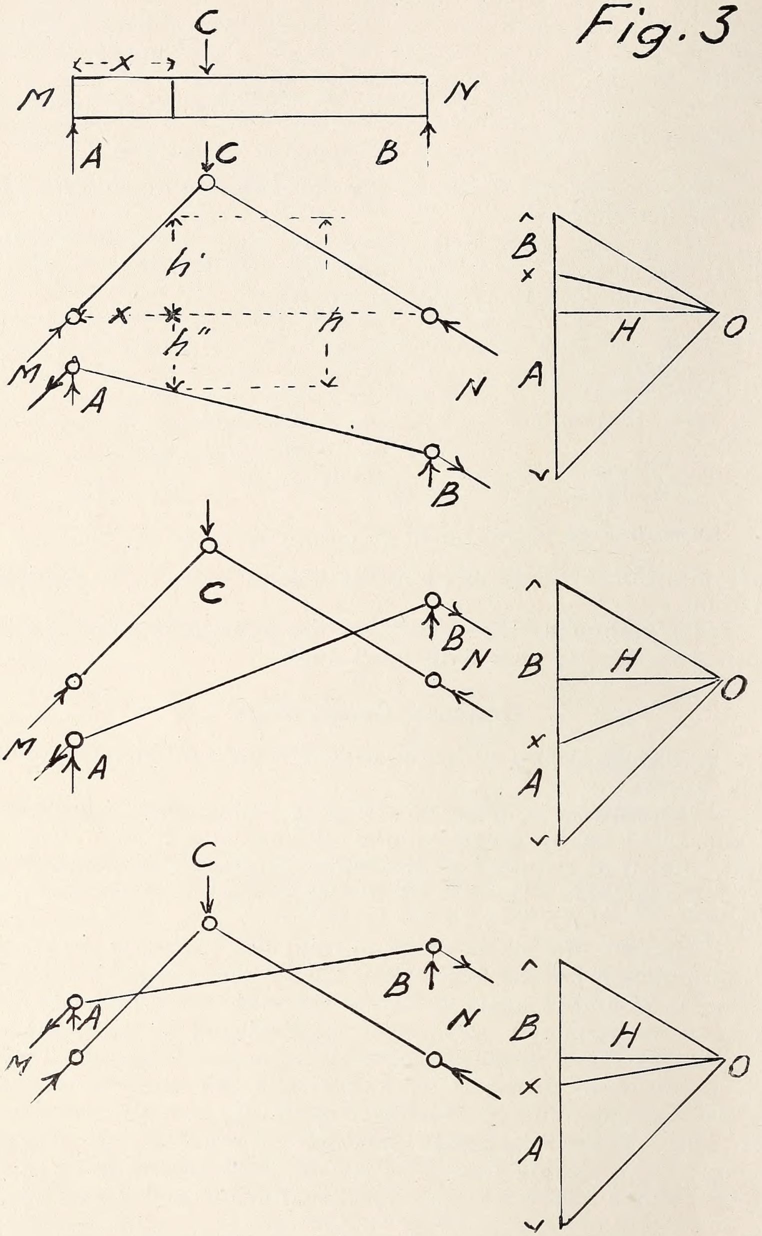
It may be useful to begin with a simple problem involving end couples.

Thus suppose a beam (see Fig. 3) supporting a single load C and acted on by given couples of moments M and N at the ends. Let it be required to determine graphically the supporting vertical reactions A and B. Three cases are worked out in the figure.

Construct the polar diagram and the funicular or equilibrium polygon for the load; then lay off the couples having the moments M and N using as forces the end forces acting on the arms of the funicular polygon of the load and forces equal and opposite to these as shown in the diagrams. The line joining the intersections of the latter forces with the end verticals will be the closing line or closing arm of the complete funicular polygon. A more accurate method of constructing the end points of the closing line is to lay off vertical ordinates in the proper senses (shown in the figure) from the end points of the funicular polygon of the loading, viz., the ordinate $\frac{M}{H}$ at the left

and the ordinate $\frac{N}{H}$ at the right-hand end. H is the horizontal pole distance in pounds.

Fig. 3



A line drawn from the pole O in the polar diagram parallel

to this closing line will divide the vertical load line into two portions representing A and B as shown.

It is evident that if the end couples be altered by equal absolute amounts the reactions A and B will remain unaltered, for the new closing line will be parallel to the old.

The bending moment at any section x is Hh when h is the vertical ordinate drawn from the closing line to meet the funicular polygon of the loading.

Writing $h = h' + h''$ where h'' runs from the closing line to meet the line joining the end points of the funicular polygon of the loading, we shall have Hh' representing the bending moment at x if no end couples act and Hh'' the bending moment due to the end couples M and N if no loading exists and if equilibrium be maintained by equal and opposite vertical reactions A'' and B'' at the ends. It is evident that if A' and B' be the vertical end reactions due to the loading alone $A' + A'' = A$ and $B' + B'' = B$; also $Hh'' = M + \frac{N - M}{l} x$ where l represents the span.

The complete funicular polygon considered as a jointed frame is thus divided on account of the end couples into two parts, each part being in equilibrium under external forces. Thus no stress exists between these parts when considered as parts of a jointed frame.

If the forces of the end couples be represented in the polar diagram and the funicular polygon be drawn in the ordinary way the portion of this polygon between the end verticals is the funicular polygon shown in Fig. 3.

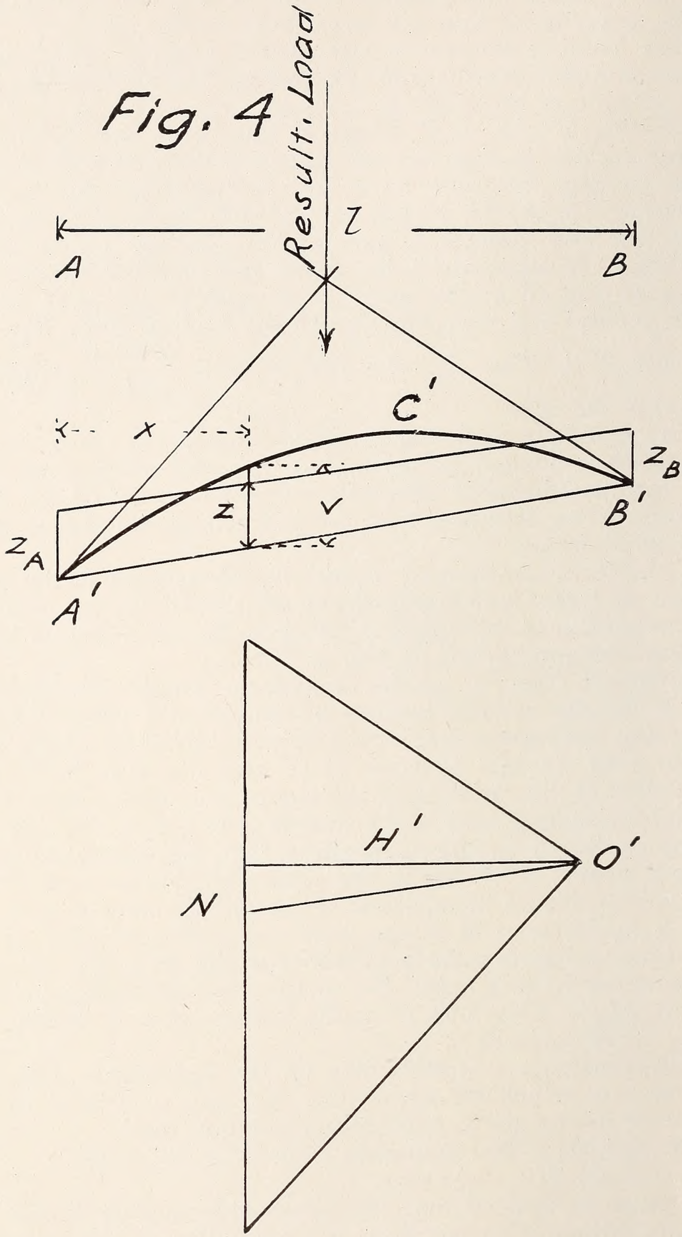
Construct (see Fig. 4) the funicular or equilibrium polygon $A'\ C'\ B'$ for the vertical loading by means of a polar diagram having any convenient pole. Any suitable divisions of the arch may be used for this purpose since this diagram is entirely independent of the variation of the quantity EI which determines the n subdivisions δs used in the summations 1, 2, 3. The annexed diagram is drawn on the supposition that the subdivisions are infinitely small. A', B' are in the same verticals as A, B.

If then x denote the abscissa of the middle point x, y, of one of the n subdivisions δs of the axis and v the ordinate of the equilibrium polygon corresponding to x the bending moment corresponding to this point due to the vertical loading will be given by $M' = H'v$ where H' is the horizontal pole distance in pounds. (See remarks.)

Now construct a straight line on the same base $A'\ B'$, the ordinates z of which for each value of x are so related to the ordinates v of the above equilibrium polygon that
$\Sigma z = \Sigma v$ and $\Sigma zx = \Sigma vx$ summing from A' to B'; thus
$\Sigma(v - z) = 0$; $\Sigma(v - z)x = 0$.

It must be noticed that the above summations do not include any ordinates except those corresponding to the values of x for the middle points of the n divisions δs of the arch.

Evidently $z = z_a + \frac{z_b - z_a}{l} x$ where z_a and z_b represent the end ordinates of the z line.



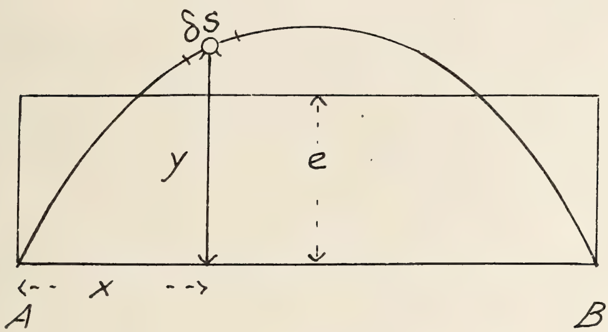
In a similar manner construct (see Fig. 5) from the n ordinates y of the axis of the arch a straight line of which the ordinates e for the several values of x fulfil the conditions

$$\Sigma e = \Sigma y; \; \Sigma ex = \Sigma yx$$

and thus

$$\Sigma(y - e) = 0; \; \Sigma(y - e)\,x = 0$$

Fig. 5



Since the axis is symmetrical with regard to its apex evidently e will be constant for all values of x and will fulfil the condition

$$ne = \Sigma y \text{ or } e = \frac{\Sigma y}{n}$$

In this case the condition $\Sigma ex = \Sigma yx$ is fulfilled necessarily and is therefore not an independent condition; if not obvious this may be shown as follows:

From symmetry:

$$\Sigma ex = \Sigma e(l - x) = \Sigma el - \Sigma ex \text{ where } l = \text{span } AB.$$

$$\therefore 2\Sigma ex = \Sigma el = nel$$

$$\therefore \Sigma ex = \frac{nel}{2}$$

also $\Sigma yx = \Sigma y(l - x) = \Sigma yl - \Sigma yx$

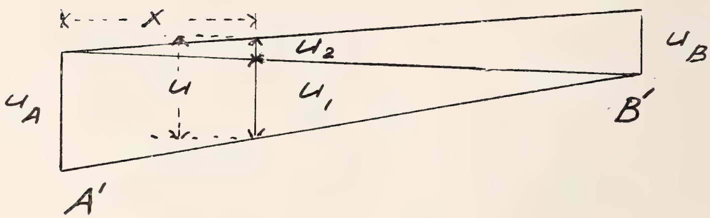
$$\therefore 2\Sigma yx = \Sigma yl = l\Sigma y = lne$$

$$\therefore \Sigma yx = \frac{lne}{2}$$

$$\therefore \Sigma yx = \Sigma ex.$$

Graphical Computation of z. (See Fig. 6.)

Fig. 6

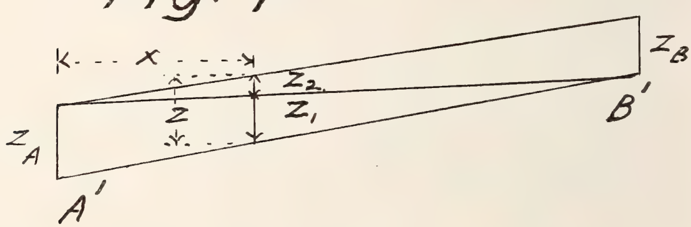


Draw any straight line to base $A'\ B'$ and let the ordinate corresponding to abscissa x be represented by u; draw the diagonal shown cutting the ordinates u each into two parts, a lower u_1 and an upper u_2 so that $u_1 + u_2 = u$.

Then write $\bar{x}_1 = \dfrac{\Sigma u_1 x}{\Sigma u_1}$; $\bar{x}_2 = \dfrac{\Sigma u_2 x}{\Sigma u_2}$

From the properties of the triangle it is evident that the values of x_1 and x_2 remain unchanged whatever be the values of u_a, u_b, hence the above construction will give the values of x_1 and x_2 for the z diagram (Fig. 7) even though the values of z are as yet unknown.

Fig. 7



Then drawing a similar diagonal in the z diagram we have

$$\frac{\Sigma z_1 x}{\Sigma z_1} = \bar{x}_1 \qquad \frac{\Sigma z_2 x}{\Sigma z_2} = \bar{x}_2$$

Also $\Sigma z_1 x + \Sigma z_2 x = \Sigma z x = \Sigma v x$ by hypothesis
and $\Sigma z_1 + \Sigma z_2 = \Sigma z = \quad = \Sigma v$ by hypothesis.
$\therefore\ \bar{x}_1\, \Sigma z_1 + \bar{x}_2\, \Sigma z_2 = \Sigma v x$; $\Sigma z_1 + \Sigma z_2 = \Sigma v$
which equations give the unknowns Σz_1 and Σz_2

$$\text{thus } \Sigma z_1 = \frac{\bar{x}_2 \Sigma v - \Sigma v x}{\bar{x}_2 - \bar{x}_1} \quad ; \quad \Sigma z_2 = \frac{\Sigma v x - \bar{x}_1 \Sigma v}{\bar{x}_2 - \bar{x}_1}$$

The following transformation may be more convenient for computation:

$$\text{Write } \Sigma vx = \bar{x}\Sigma v \text{ and compute } \bar{x}$$

$$\text{Then } \Sigma z_1 = \frac{x_2 - \bar{x}}{x_2 - x_1}\Sigma v\;;\quad \Sigma z_2 = \frac{\bar{x} - x_1}{x_2 - x_1}\Sigma v.$$

Now from the properties of a triangle it is evident that

$$z_a = \frac{\Sigma z_1}{\Sigma u_1} u_a \text{ and } z_b = \frac{\Sigma z_2}{\Sigma u_2} u_b$$

so that substituting in these expressions the values already found for Σz_1 and Σz_2 the values of z_a and z_b become known.

The z diagram can now be constructed and the value of z determined by measurement or computation for each value of x.

The constructions Fig. 6 and Fig. 7 are usually made directly on Fig. 4.

It is evident that $\frac{u_a}{\Sigma u_1} = \frac{u_b}{\Sigma u_2}$ and that the u line may as well be drawn parallel to $A'\ B'$ and one triangle computed instead of two.

Analytical Computation of z.

z may be computed analytically as follows:

$$\Sigma z = \Sigma v$$

$$\Sigma zx = \Sigma vx$$

$$z = z_a + \frac{z_b - z_a}{l} x$$

Substituting from the last equation in the first

$$nz_a + \frac{z_b - z_a}{l}\Sigma x = \Sigma v$$

Substituting similarly in the second equation

$$z_a\Sigma x + \frac{z_b - z_a}{l}\Sigma x^2 = \Sigma vx$$

$$\text{thus } \left(n - \frac{\Sigma x}{l}\right) z_a + \frac{\Sigma x}{l} z_b = \Sigma v$$

$$\left(\Sigma x - \frac{\Sigma x^2}{l}\right) z_a + \frac{\Sigma x^2}{l} z_b = \Sigma vx$$

which equations will give z_a and z_b in terms of the known quantities l, n, Σx, Σv, Σx^2, Σvx.

z may then be computed for each value of x.

The results are

$$z_a = \frac{\Sigma v\Sigma x^2 - \Sigma x\Sigma vx}{n\Sigma x^2 - (\Sigma x)^2}$$

$$z_b = \frac{\Sigma v.\Sigma x^2 - \Sigma x.\Sigma vx + l\,(n\Sigma vx - \Sigma x\Sigma v)}{n\Sigma x^2 - (\Sigma x)^2}$$

$$z = \frac{\Sigma v\Sigma x^2 - \Sigma x\Sigma vx + x\,(n\Sigma vx - \Sigma x\Sigma v)}{n\Sigma x^2 - (\Sigma x)^2}$$

The z's and e's having been determined the next step is to compute the summations

$$\Sigma(v - z)y = P \qquad \Sigma(y - e)y = Q$$

Then writing $v' = \frac{Q}{P} v$; $z' = \frac{Q}{P} z$ we have $\Sigma z' = \Sigma v'$; $\Sigma z'x = \Sigma v'x$. Therefore

$$\begin{aligned} \Sigma(v' - z') &= 0 & \Sigma(y - e) &= 0 \\ \Sigma(v' - z')y &= Q & \Sigma(y - e)y &= Q \\ \Sigma(v' - z')x &= 0 & \Sigma(y - e)x &= 0 \end{aligned}$$

Hence by subtraction

1′ $\Sigma(e - z' + v' - y) = 0$

2′ $\Sigma(e - z' + v' - y)y = 0$

3′ $\Sigma(e - z' + v' - y)x = 0$

in which $e - z' = e - \left\{ z'_a + \frac{z'_b - z'_a}{l} x \right\}$

4′ That is $e - z' = e - z'_a + \frac{e - z'_b - (e - z'_a)}{l} x$

5′ $v' = \frac{Q}{P} v = \frac{M'}{\frac{P}{Q} H'}$

Comparing these equations with the equations already established, viz:

1. $\Sigma(y'' + y' - y) = 0$
2. $\Sigma(y'' + y' - y)y = 0$
3. $\Sigma(y'' + y' - y)x = 0$
4. $y'' = \frac{M_a}{H} + \frac{\frac{M_b}{H} - \frac{M_a}{H}}{l} x$
5. $y' = \frac{M'}{H}$

we see that both sets involve the quantities l, x, y and M' in the same way and that $e - z'_a$, $e - z'_b$, $\frac{P}{Q} H'$ of the first set and $\frac{M_a}{H}$, $\frac{M_b}{H}$, H of the second set are respectively involved in the same way.

Consequently

$$e - z'_a = \frac{M_a}{H} \; ; \; e - z'_b = \frac{M_b}{H} \; ; \quad \frac{P}{Q} H' = H$$

In other words the graphical construction gives the true values of the horizontal thrust and the bending moments at the ends of the arch.

Fig. 8 is now constructed from Fig. 4 by making $v' = \frac{Q}{P} v$, $z' = \frac{Q}{P} z$ and making the upper line of the z' diagram horizontal, its length being equal to l the span AB.

Fig. 8

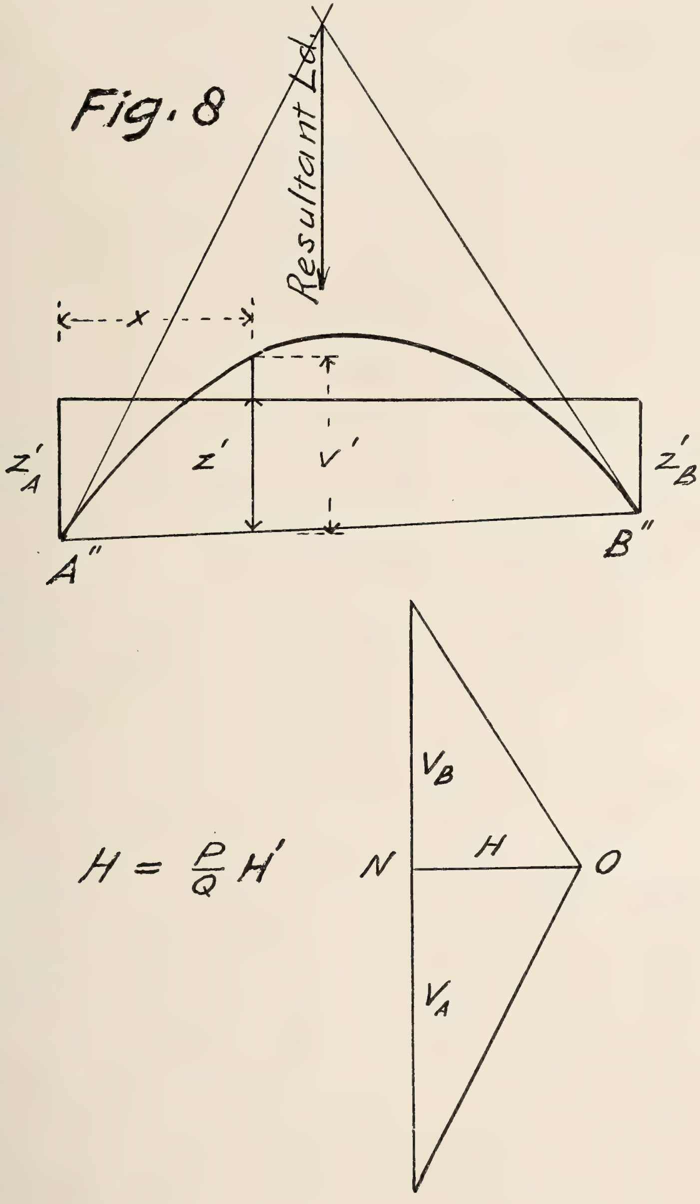
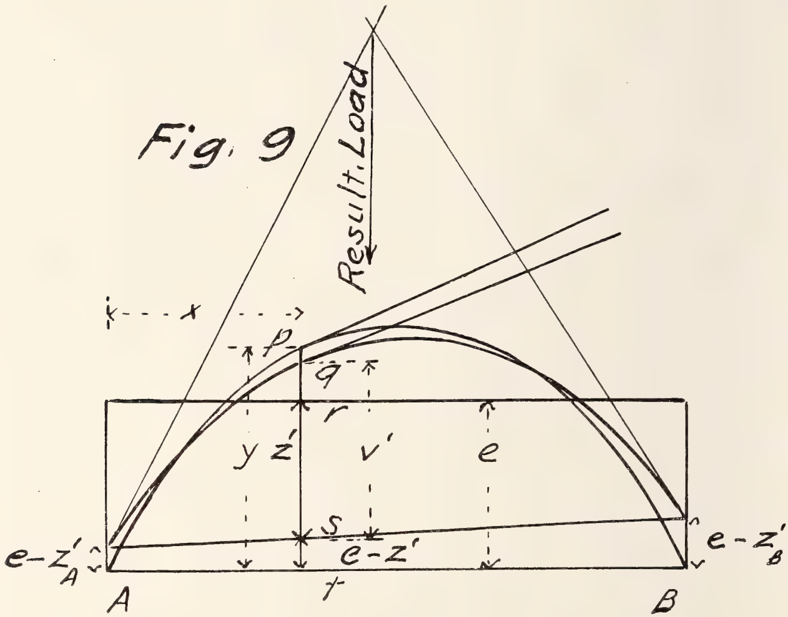


Fig. 9 is now constructed by applying Fig. 8 to Fig. 5 so that the horizontal z' line of the former coincides with the horizontal e line of the latter.

Draw the ordinate in Fig. 9 for abscissa x and let it cut the various lines in the points p, q, r, s, t. Evidently $ts = e - z'$; $sq = v'$ and $tp = y$. Thus $M = (ts + sq - tp)H = -qp \times H = pq \times H$. Hence the ordinate corresponding to M for any section x is that part of the ordinate at x intercepted between the axis of the arch and the curve of moments, reckoned positive if drawn upwards from the axis. In the figure this ordinate is negative.

The moment M'' due to the end couples M_a and $-M_b$ being equal to $(e - z')H$ or $He - Hz'$ may be analyzed as follows:

Fig. 9



The bending moment $-Hy$ due to the horizontal thrust of the abutments generates an opposing bending moment He due to the fixed directions of the axis at the abutments; the bending moment Hv' due to the vertical forces generates an opposing bending moment $-Hz$ due also to the fixed directions at the abutments and the sum of these $He - Hz'$ is the total bending moment due to the fixed directions at the abutments.

There are thus two bending moments Hv' and $-Hz'$ due to the vertical system of forces and two bending moments $-Hy$ and He due to the horizontal system of forces. The sum of these four moments is the resultant bending moment M.

The horizontal thrust H is itself due to the vertical system

of forces, being caused by the action of the latter on the elastic body of the arch which is prevented from spreading by the fixed abutments.

Vertical Reactions at A and B.

These are obtained from the polar diagram Fig. 8. It is constructed as follows: from the pole O' Fig. 4, draw a line $O\ N$ parallel to the closing line (the z line) to meet the load line, and transfer the point N so obtained to the load line of the polar diagram of Fig. 8. From N in the latter diagram lay off horizontally a line representing the true horizontal thrust H; the end O of this line represents the correct position of the pole in Fig. 8 and the point N divides the load line into the portions representing the vertical reactions V_a and V_b as indicated. The reasons are as follows:

The z line in Figure 4 is the closing line due to the combination of the loading with end couples of moments $-H'z_a$ and $+H'z_b$; these moments by construction are equal to $-Hz'_a$ and $+Hz'_b$, therefore the vertical reactions in the combination represented in Fig. 8 must be the same as in the case of Fig. 4. Now the closing line in Fig. 8 is horizontal; hence if H be laid off horizontally from N in Fig. 8 as shown, the proper position of the pole O will be found for the combination shown in Fig. 8. The true end moments indicated in Fig. 9, viz., $M_a = H(e - z'_a)$ and $-M_b = -H(e - z'_b)$ are not the same as the end moments in the case of Fig. 8 which are $-Hz'_a$ and $+Hz'_b$. However, they also give a horizontal closing line, viz., the base $A\ B$ of Fig. 9, so that the position of N in Fig. 8 indicates the true vertical end reactions. See discussion of Fig. 3.

Thrusts and Shears at a Cross-Section.

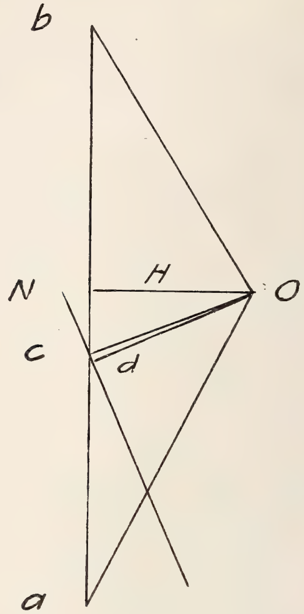
Consider the cross-section corresponding to x.

In the polar diagram of Fig. 8 let $c\ a$ (see Fig. 10) represent the load between the verticals at A and x; join $O\ c$; draw $c\ d$ parallel to the cross-section at x and drop the perpendicular $O\ d$ on $c\ d$. Then it is evident that $c\ O$ represents the oblique thrust on the cross-section, $c\ d$ its tangential resolved part or the shear (negative by the rule of signs) and $d\ O$ the normal thrust.

The position of the point of action on the cross-section, of the thrust $c\ O$, is obtained by drawing the tangent to the v' curve at the point corresponding to x to meet the cross-section in question. It nearly coincides with the point of intersection of the v' curve with the cross-section.

Evidently $O\ d$ is parallel to the tangent to the axis at p and $O\ c$ parallel to the tangent to the v' curve at q in Fig. 9 or Fig. 2.

Fig. 10



Remarks.

In this investigation the shortening of the elastic arch arising from the axial thrusts at the various cross-sections has not been taken into consideration nor the effects due to temperature changes.

The loading has been assumed to be vertical; that is to say no horizontal or spandrel reactions due to the load have been considered. The horizontal thrust is thus constant from abutment to abutment.

In computing the bending moment M' due to the loading, the load from the abutment up to the section in question has been assumed to be the weight of the material (including that in the arch itself) which lies between the verticals drawn through the axial points of the springing section A or B and of the section considered; similarly the whole load on the arch has been assumed to be the weight of the material (including that in the arch) lying between the verticals through the axial points A and B at the springing planes. The weights of the portions of the arch outside of these verticals and their super-

incumbent loads have therefore not been included in the computation.

The errors due to this method of computing the bending moments due to the vertical loads, become less, the flatter the arch is, that is the more nearly it approaches in form the horizontal beam. Similarly in a given arch the errors are least at the apex where the axis is horizontal, and greatest at the abutments.

The end tangents shown in Figs. 4 and 8 evidently give the lines of action of the abutment reactions for the assumed system of loading.

The abutments are assumed to be inelastic and rigid.

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COAL AND THE LOCOMOTIVE.

GEORGE S. HODGINS (S.P.S., 1881).
Managing Editor, Railway and Locomotive Engineering.

It has been poetically said that coal is but the imprisoned sunbeams of the past, and although this may not be literally correct, yet it is a statement which embodies something of truth. Geological research has established the vegetable origin of coal, and the original plants, from the remains of which our coal was formed, drew their substance from the luxuriant soil of that far-distant epoch in which they lived. They separated out carbon and liberated oxygen under the genial influence of the sunshine of the very remote past. The predominant feature of the process here alluded to, was the chemical transformation from soil and air, under the sun's beams and by reason of the heat derived from that source.

George S. Hodgins,
Managing Editor, Railway and Locomotive Engineering.

Speaking of the Palaeozoic age and of the vegetable forms from which our coal is derived, Hugh Miller says, "In no other age did the world ever witness such a flora; * * * A rank and luxurious herbage cumbered every foot-breadth of dank and steaming soil, and even to distant planets, our earth must have shone through the enveloping clouds with a green and delicate ray." The growth of the plant was then for the most part a chemical process; a separation of elements and a union of others. For our purpose it may be summarized as the separation of the oxygen from the carbon and from the hydro-carbons of the plant, and the long burial of the fallen forests did not disturb these conditions as established when the plant lived. The solar energy effected the chemical changes which are reversed when coal is burned to-day.

Energy has been defined as the ability to do work, and energy may be present in the active or in the passive form—it may be potential or it may be kinetic. The passive or potential form can be seen when the hammer of a pile-driver is raised aloft, and hangs motionless and inert at the top of the guides. The attraction of gravity acts upon it, but until the detent is thrown out, the hammer cannot do work. It has, however, the potential energy of position with reference to the pile below. So it is with coal. It has not to be endowed with its energy by mechanical means like the hammer of the pile-driver. It possesses, by virtue of the solar energy of a by-gone age, the potential energy

of chemical separation, and awaits only the presence of appropriate conditions (as the hammer waits for the detent) to burst into flame, and give back, by the union of the long separated oxygen and carbon, the energy stored up in its substance in the days when the earth was young.

This coal, heaped upon the tender of a locomotive and containing potentially the slowly accumulated energy of an era when mankind did not exist, yet finds the necessary temperature conditions, for liberating its stored up energy when thrown into the firebox. Here in the flame-storm above the white-hot fuel, the concentrated effects of solar energy are given off in the form of radiant heat and glowing gas which beat against the side and back sheets of the firebox, strikes up against the crown sheet, and rush against the tube sheet and through the flues. The steel plates of the firebox quickly transmit the radiant vibrations—this mode of molecular motion which we call heat, and if one may so say, these vibrations stream through the plates and out into the mass of water in the boiler.

Here the molecular agitation set up in the plates communicates itself to the water, and so intense are these heat vibrations, that the water ceases to retain the liquid form. Its particles are moved about with such exceeding rapidity that they are compelled to assume the gaseous state in order to give scope and freedom to the enormously rapid motion which they are compelled to adopt. Thus is formed what we call steam. The gaseous form of matter demands greater space for the swing and sway of its atoms, than is required in the liquid state. This demand for increased space, in a confined vessel like a boiler, produces a violent action of the particles, with more frequent and more powerful collisions between each particle. This phenomenon, we recognize as pressure. It therefore becomes apparent that the sun's action, directed upon the plant life of this earth, at a period so remote that the mind cannot grasp it, has waited through many ages to be so liberated and so employed, as to produce for us, what we prosaically describe as steam under pressure.

The opening of the locomotive throttle valve allows steam under pressure to flow through the dry pipe, down the branch pipes to the steam chests and thence to the cylinders. Here the vibratory action, deadened somewhat by hammering upon the walls and passages it has encountered and traversed, is a little less active, and we speak of it as having slightly cooled. Nevertheless, it continues a bombardment on piston and cylinder cover, and on the cylinder walls, as the vibrating particles of steam dash hither and thither in their endeavor to expand or run the full extent of their normal excursions. The fixed cylinder-cover remains unmoved, save that its particles imbibe the vibrations of the steam particles and so grows hot. The piston, however, capable of molar motion, is subjected to the myriad blows of the dancing steam particles and the piston

gives way and slowly recedes before the gaseous onslaught of a billion atoms.

The piston moves back as a whole, though its particles are agitated like those of the cylinder cover, and the moving piston concentrates its action on the piston-rod. The rod forces the crosshead to move backward and this in turn communicates its motion to the connecting rod of the engine, and this being fastened to the crank-pin pushes it backward on the lower half of its course; the driving wheel revolves, and the engine moves ahead.

Here the curious phenomenon of the push on the crank-pin on its lower half-circuit, causing a forward motion of the engine, makes its appearance. Ordinarily if an object is pushed in any given direction, it moves in that direction, yet here we have a well-defined backward motion of the crank-pin producing a forward movement of the engine. The crank-pin is pushed backward on the lower half of its course and if this push could be given by a squad of men standing on the ground, the engine would move backward and not forward as we know it does. The reason why the engine moves forward when the crank-pin below the axle, is pushed backward by the agency of steam can be explained by a little alteration of the mechanism.

If the "big end" of the connecting rod was uncoupled from the crank-pin and placed so that it would rest against one edge of a tie on the track, the backward push of the steam on the piston would force the crosshead back, and the engine would go ahead. It would then be very evident that the connecting rod itself, or indeed the piston and crosshead, did not move at all, and the question arises from whence comes the motion of the engine, for it undoubtedly moves forward? We have now to return to a consideration of the bombarding action of the particles of steam in the cylinders. The bombardment of steam particles took place not only on the piston but on the walls of the cylinder and on the front cover. This incidentally shows that the pressure of steam acts equally in all directions. As the piston is held stationary by the connecting-rod with big end against the tie, the pressure of steam acting on the front cover moves it ahead. The cover being rigidly connected to the cylinder, and the cylinder being bolted to the frame; the cover, cylinder and frame together move forward, and as it were, draw the cylinder over the piston, and the forward movement of the frame carries forward the driving axle-box, and the wheel rolls forward. In this case the engine would only move forward a distance equal to the stroke.

When the connecting rod is attached to the crank-pin in the usual way and the pin acted upon by the backward pressure of the connecting rod, the wheel becomes practically a lever. of the second class, where the fulcrum is at the point of contact of wheel and rail, the power is applied at the axle box, and the resistance is at the crank-pin. The arm of the power is the dis-

tance from the axle-box to the rail, and the arm of the resistance is from the crank-pin to the rail. The power and the resistance being equal the greater length of the power arm causes it to predominate and compel the engine to go ahead. In this case the fulcrum constantly shifts, a new lever being, as it were, formed momentarily. The engine will now move a distance equal to the half circumference of the wheel.

As soon as the crank-pin comes above the centre of the wheel and enters upon its course above the axle, the piston is pulled forward and the back cylinder head and the frame are thrust back. The wheel again becomes a lever of the second-class with fulcrum at the rail, power applied to the pin, and the resistance at the axle. The leverage being now in favor of the pin by reason of its greater distance from the rail, than that from axle to rail, the force on the longer arm of the power prevails, and the engine continues to move forward. In the former case we spoke of the power being applied at the axle, and the resistance at the pin, when on its lower half circuit, in order to maintain the idea of the power producing the result observed. In this case with pin on its upper half circuit, we speak of the power being applied to it and the resistance as applied at the axle, for the same reason. In these two examples, for sake of uniformity, the arm of the power is in each case, taken as greater than that of the resistance. The predominence of the power, when viewed in this light, is apparent.

When examining the Stephenson link motion and D-slide valve of an ordinary 4-4-0 type of locomotive, one might be inclined to enquire why an engine starts in a predetermined direction from, say, the forward dead centre. If, for example, the right-hand piston is at the beginning of its backward stroke, and the reverse lever is in the extreme forward notch, the slide valve will be found to be open, the amount of full-gear lead, say 1-8 of an inch. If the reverse lever is moved backward to the centre of the quadrant, the valve opens the port further, until it reaches its mid-gear lead position. This is greater than the full-gear lead. If the motion of the reverse lever is proceeded with to the back notch, the valve moves to its full-gear lead position, which is, other things being equal, 1-8 of an inch. The question is, if steam be admitted to the cylinder under these conditions, which way will the engine move? Valve and piston are in the same position with reverse lever full forward or full back.

The obvious answer is that if we had only one side of the locomotive to deal with we might not make a very satisfactory start. The point, however, to remember is that if the reverse lever was in full forward gear and the engine attempted to go backward the small lead opening would be very quickly closed, but if the engine elected to go forward, the lead opening would be increased very promptly. At the time the right side of the engine is in full gear ahead, the left side of the engine, having its crank-pin set a quarter turn behind the right pin, is on the

top quarter and the left slide valve is open so that steam can only enter the left cylinder behind the piston. Under these circumstances the engine can only go forward. The slightest motion in that direction places the right crank-pin below the centre and the engine moves ahead as a natural consequence.

We have, up to this point, endeavored to trace, though in a somewhat disjointed way, the present-day action of the long-gone-by power of the sun, until it re-appears in the motion of a modern locomotive. We have seen how the carbon and oxygen, united again in the firebox, gave back as heat, the energy which had originally been expended to separate them, and that the potential energy resident in the coal was not destroyed through the lapse of time. The accumulation of this potential energy by the plants was slow and gradual. Each one germinated, grew, waxed great and fell. Myriads of trees followed in the tardy process and were at length overthrown. The submerging, burying, solidifying of the forests required a period of time to which recorded history is as but yesterday. In the slow march of the years they were crushed down and built together into what we call coal. This age-long process has stored up for us, unused, the energy we now employ with prodigality as the spendthrifts of the ages. That a man may travel swiftly from Toronto to Hamilton there has been drawn from the storehouse of nature a supply of the once radiant energy of the sun, slowly gathered by plant life through long stretches of a distant past, and it is faithfully given back in the form of motion. The sun-god is still the power that speeds our trains over the iron way.

ENGINEERING IN CANADA.

WALTER J. FRANCIS, M.C.Soc.C.E., M.A.Soc.C.E.

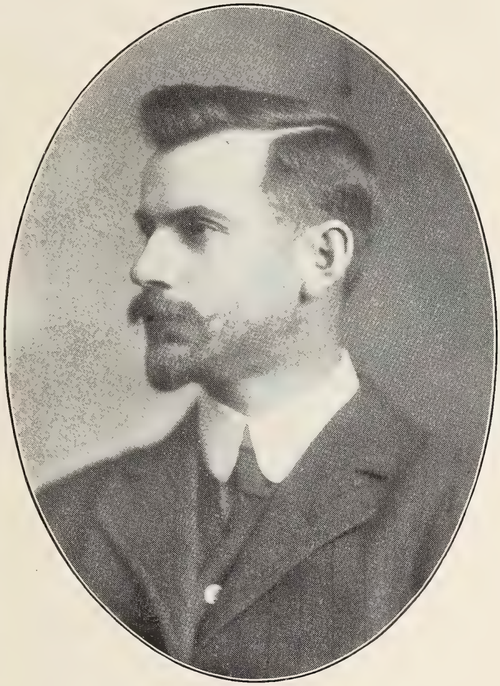
Canadian Correspondent, The Engineer, (London),

It has been said that there is nothing new under the sun. Whatever there may have been in the untold ages of the past it is certain that for a score of centuries the human race did without countless things that to-day are considered necessities. From the days of Nebuchadnezzar, King of Babylon, to the time of George IV of England, and for even a longer period we did pretty much the same things in the same way, and the trifling changes made were due to the influence of climate more than to any other cause. The battles depended largely on the work of the individual soldiers in hand-to-hand encounter. Horses and men provided the sole means of transportation and communication by land. The only source of power in nature that was applied to the use and convenience of man was the wind —to grind corn and to propel ships. Nevertheless it was during these years that literature, architecture and art reached perfection so great that they stand to-day the masterpieces of the

world, the examples which our most ardent students seek to copy, and the pride of the most cultured and scholarly.

The remarkable skill attained by the masons in pyramid construction, in the building of temples and, later, in cathedrals may account in some measure for the noteworthy accomplishments of the Romans in waterworks and roadmaking two thousand years ago, all being work in stone and consequently somewhat related in character.

It remained for the nineteenth century, however, to make advances along other lines that have revolutionized the world, advances which in effect may yet surpass the most sanguine dreams of the optimistic prophet. To-day people do things in a matter-of-fact way that would have been considered impossible fifty years ago. Who can foretell for ten years, say, what will be the developments in aerial navigation, in electricity with its countless interests, in chemistry or in surgery? With one exception surgery has advanced more than any other branch of learning in these latter days. That exception is engineering. Mankind must thank engineering for converting luxuries into necessities. Engineering has given the world its factories, its telegraphs, its steamships and its railroads. Even architecture, in spite of her ancient dignity, must acknowledge that her devotees are enabled to cope with the building problems of the day because engineering has produced the tall framework of steel and of reinforced concrete. Surgery, for whose youthful vigor the discovery of anaesthetics is responsible, may yet resort to electricity to render her subjects insensible to pain if one may judge of the articles in the current magazines. Our universities, so long sacred to classics and mathematics, are now unable to accommodate the young men who throng there to study applied science.



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It would be difficult indeed to eliminate the engineer from the world problems of to-day. He it is who develops the mining and produces the steel that spans our rivers, that forms a wonderful grillwork over our continents, that makes possible on our oceans the multitude of floating fortresses and cities, and that constitutes the myriad of machines which by their ingenuity compel us to stand in awe and admiration. He it is who harnesses the Niagaras of the world to provide us transportation, to transform the night of our cities into noonday, and to turn the wheels of commerce. The engineer has developed the details of sanitation and has thus bestowed upon mankind one of the greatest of blessings. Take from us the telegraph, the telephone and the wireless; take from us the typewriter, the talking-machine, the bicycle and the automobile, and we shall appreciate a little more fully some of the efforts of the engineer. The four words which comprehend "engineering" more completely than any others perhaps are power, manufacturing, communication and transportation. These four words embrace a very large part of the civilization of the present time. The greatest of these is transportation.

The charms of Canada, fairest daughter of the Mistress of the Seas, have naturally not been lost on the engineer. The growth of the two has been contemporaneous. Let us for a short time consider what has already been done, after which some remarks pertaining to the future of engineering in Canada may not be out of place.

It is not many years ago that Canada was described in almost the same words by which the schoolboy was taught to define a line—length without breadth. The land area bounded by the Atlantic and the Pacific, and lying between the 49th parallel and the North Pole, is very great; but most of it is still ruled by the unfettered hand of Nature, only a comparatively narrow strip along the southern boundary being settled and devoted to cultivation. The Maritime Provinces being accessible by sea from the old land were the first to be populated. The navigators continuing up the mighty St. Lawrence are responsible for the settlement of Quebec and the old part of Ontario. The needs of the district were not great but they taxed the engineering and financial resources to their utmost in providing the railways which now constitute a considerable part of the Grand Trunk System, and the artificial waterways that were constructed to overcome the obstructions in navigation in the Niagara River and along the St. Lawrence. The earliest noteworthy achievements in bridge building were the Victoria Tubular Bridge, built by Stevenson & Ross in 1859 over the St. Lawrence at Montreal, and the Suspension Bridge at Niagara built about the same time by Roebling. The opening up of Manitoba in the early seventies marked the first progress westward. The great Northwest was a desert littered with buffalo bones.

The wheat fields were as yet undreamed of. Fort Garry, by which name Winnipeg was first known, was a small village and Hudson Bay Company's post. Then came the building of the first transcontinental railway, the greatest railway problem the engineer had yet been called upon to solve. How well it was done has been amply proved by its subsequent use. To the construction of the Canadian Pacific Railway Canada owes the colonization of the West. The settlers poured in, the wheat fields were developed and Nature assisted by the farmer provides a volume of freight that taxes the facilities of some of the largest carriers in the world. The signpost of every new railway station is a grain elevator or group of them. In recent years we have seen the phenomenal development of the Canadian Northern, the Mackenzie and Mann system, itself now almost a transcontinental system. Within the next five years a third transcontinental line, the Grand Trunk Pacific, will have been completed, which will materially widen the narrow strip of settlement by opening up a parallel zone of wild country on the north. Surveys for new branch lines are extending in every direction from the main systems. The transportation problem becomes greater. Canada is a country of distances. Her geography necessitates the development of her transportation routes along east and west lines. The fact of having a complete railway system across the continent renders it practicable to operate a line of carriers on the ocean at either end, as the C. P. R. have done in their Atlantic and Pacific lines of steamships. These railways with their ever-growing branches are very fully occupied in transporting the wheat from the great West to the ports on the Pacific, to the head of the Great Lakes or to the port of Montreal.

The period of development of the western prairies has also seen the improvements to navigation in the great St. Lawrence route. About ten years ago the Soulanges Canal, one of the artificial links in this immense chain of navigation, was completed and stands as a masterpiece of 15-foot canal construction. The never-ceasing procession of freight boats passing day and night in navigation season through the magnificent locks on the St. Mary River at Sault Ste. Marie represents the largest tonnage passing through any canal in existence. The River St. Lawrence, navigated by ocean vessels to the port of Montreal, 1,000 miles inland, has been improved so that there is a lighted and buoyed channel at least 450 feet wide, with a minimum depth of 30 feet at extreme low water. Three years ago a 35-foot channel was commenced by the Department of Marine and Fisheries from Montreal to the sea.

During the same period of western progression the carrying capacity of the railways to compete in some measure with the waterways has increased tremendously, necessitating heavier rails, bridges and rolling stock. The increased traffic has com-

pelled the railway companies to drive two tunnels under the water route, one at Sarnia and the other at Detroit, the former having been operated electrically since the summer of 1908. The historic Victoria tubular bridge has been rebuilt into a modern steel through bridge, and the well-known Niagara Suspension has given place to a magnificent steel arch. All over the country the bridges have been rebuilt, the wooden ones being replaced by steel, and the lighter steel structures by heavier ones. Many interesting and important examples of the bridge-builder's art of every type have been erected throughout the Dominion.

Naturally adequate terminal facilities became necessary and as a result we see the immense elevators at Port Arthur and Fort William and at other points on the Great Lakes. The port of Montreal, which at present can be used for navigation purposes only seven months of the year through adverse climatic conditions, has developed until it stands to-day, according to the statement of the president of the Board of Harbor Commissioners of Montreal, third in handling capacity per month of all British ports.

While the West has been developing and expanding, the population of the East has grown with remarkable strides. Of the Ontario peninsula this is particularly true, the inhabitants having settled down to highly developed agriculture and fruit growing. Villages and towns are thriving everywhere. The cities have grown with great rapidity, due in a great measure to the evolution of electric traction. Twenty years ago the bob-tailed horse-car running on a single track was a not unfamiliar sight in our cities. To-day sixty-foot electric cars on a two-minute schedule are incapable of handling the passenger traffic in the cities, the streets are congested with traffic, and elevated and underground lines are talked of. Montreal boasts a population of half a million and Toronto 400,000.

The application of electricity to modern needs has played a most important part in the upbuilding of the cities and in manufacturing. In older Ontario electric lines join many of the towns and villages together and bring the city markets within easy reach. The cheap production of electric current has meant that practically all the waterfalls in the inhabited districts have been utilized, and it may be said that every community of importance in the Dominion has its own electric light even at the comparatively greater expense of steam production. Coal occurs in Canada only in the extreme East and in the Rockies, leaving the great middle distance to depend on fuel transported great distances or on water-power.

The most important hydro-electric developments of Canada are of course at Niagara, where it is estimated 5,000,000 continuous electrical horse-power can be produced. Of this about one-tenth will be utilized when the stations now running are fully equipped. Four stations on the Canadian side can produce about 450,000 electrical horse-power. Of this quantity the por-

tion now being taken up by the Ontario Government as distributors, acting as the Ontario Hydro-Electric Commission, will be transmitted at 110,000 volts over the whole of the Ontario peninsula distances up to two hundred miles. The construction of these high-voltage lines is now proceeding and is near completion. Already Niagara power operates the electric street cars at Toronto, 80 miles distant.

Throughout the populated parts of the country, excepting perhaps in the extreme east where coal abounds, there are hydro-electric developments. Near Vancouver the mountain streams are harnessed. At Nelson the Kootenay River furnishes 20,000 horse-power for the mining of the district. Outside of Winnipeg the Winnipeg River provides over 20,000 horse-power for the city. At Sault Ste. Marie about 25,000 horse-power is used, chiefly for industrial works. The city of Montreal uses for light, heat and power from 30,000 to 53,000 horse-power developed at Lachine, Chambly and Shawinigan. Near the city of Ottawa about 35,000 horse-power is developed for civic use and for manufacturing. In addition to these there are a great many smaller plants in operation and under construction.

The mining interests have also been of importance in developing the country. The coal mines of Nova Scotia, and of the Rocky Mountains, as well as the lignite of Alberta must be mentioned. The gold of British Columbia and the Yukon likewise had its effect. The silver fields of Cobalt and the nickel deposits of Sudbury are known the world over.

In education what do we find? Thirty years ago McGill University had less than fifty graduates in engineering as a result of a course established twenty-five years previously. At that time the Toike Oikes had not begun to exist. Now McGill has practically a thousand graduates in applied science. Less than thirty years ago the first graduate in engineering at Toronto left the college halls. Now they leave by the hundred each year and the University of Toronto claims over a thousand engineering graduates. From the Royal Military College at Kingston each year about thirty young men enter practical life with a training in civil and military courses. The universities of the other provinces also have engineering faculties, and the Canadian graduates in engineering now number considerably over two thousand.

The engineering work of the future in Canada is great. Development along present lines of the art means much municipal work, power development and transportation. Before many years Canada will have a number of very large cities. Montreal, Toronto, Port Arthur, Winnipeg, Edmonton, Vancouver and Prince Rupert will be very important centres of population and distribution, presenting all the problems in water supply, sewage disposal, passenger and freight handling, and civic work. In addition to these there will be an immense number of smaller centres. Civilization will spread gradually northward. The

Peace River country will be thrown open to settlers at a very early period. The untold wealth of the Rockies will be available. The water-powers adjacent to the new settlements will all be utilized. The older part of Ontario will become a manufacturing district by the use of the white coal from Niagara and the Ottawa. The important rapids on the St. Lawrence will be developed for power and manufacturing purposes. The practically unknown district of northern Quebec with its mineral and timber wealth and unlimited water-powers only awaits the arrival of men and money. The railways will increase their branches everywhere. A new route will be created to Europe by joining the Winnipeg district with Hudson Bay—indeed, part of the money for the construction was voted at the present session of Parliament. The waterways will be materially improved. Deeper river and lake navigation will be provided between Montreal and Port Arthur. The Georgian Bay Canal, being the canalization of natural rivers and lakes along the Ottawa from Montreal to Georgian Bay, will surely be constructed in the near future. The railways will be operated largely by electricity instead of by steam. The ocean navigation to Montreal will be in use the whole year round by the aid of ice breakers operating between Quebec and the Canadian metropolis. All this means highly developed terminal facilities, and a quantity of rolling stock and machinery that is difficult to comprehend.

What of the future along lines not yet fully developed? It does not require any great flights of fancy to locate regular lines of airships of some type. The monorail railway is undoubtedly past the experimental stage. The future is more likely to be marked by development and improvement rather than by fundamental invention. Someone has said that the only thing man has ever invented is the wheel. Every other mechanical element he has used he has copied in some form or other from nature. He is an imitator and improver. In the latter years he is developing himself in that way. He may shortly discover that his electric wires are quite unnecessary, and that he makes his machines too complicated. He already knows they are extremely wasteful, that he obtains in his steam plants, for instance, only about 5 per cent. of the heat value of the coal he burns and wastes the other 95 per cent. New sources of power may be discovered. In thirty years hence the people may respect our limited scientific knowledge as little as we do that of our forefathers of fifty years ago. Time only will tell.

There is one other phase of the subject of engineering that I have not referred to. We have spoken in a general way of what the engineer has done and may yet accomplish. What he has not succeeded in doing is well illustrated by a story told to a university class in engineering economics by their honorary lecturer, who by the way is the first Toronto graduate in mechanical engineering. Certain Simians having a little more brains than

their fellows used sticks with which to knock down their cocoanuts. They were the first engineers. Another Simian having still more grey matter congratulated them on their ability to select suitable sticks. Impelled by the flattery they went for more sticks, leaving him to knock down the nuts. He was the first financier. We have continued to gather the sticks, leaving the financiers to carry on their work. Maybe we shall yet learn enough to knock down the nuts for ourselves. Time will tell.

COST OF SEWER, MUSKOKA, ONT.

E. A. JAMES, B.A.Sc., A.M.C.Soc.C.E.

In September, 1908, the Canadian Pacific Railway opened their Toronto-Sudbury line. This line, two hundred and sixty miles long, runs from Toronto in a northly direction, leaving the Owen Sound branch at Bolton Junction, it passes to the west side of Lake Simcoe and crosses the G.T.R. Collingwood branch on the level at Utopia; the Penetang branch on the level near Coldwell Junction and the Midland branch on the level east of Coldwater. The line continues north, west of Muskoka Lakes, crossing over-head the G.T.R. (Canada Atlantic Division) near Parry Sound, and joining the main line of the C.P.R. at Romford Junction, a station seven miles west of Sudbury.

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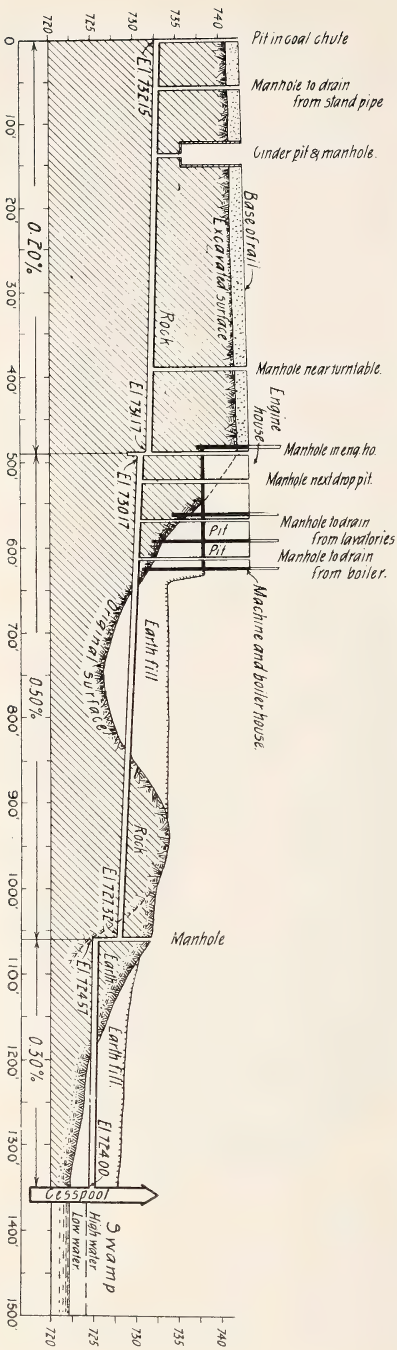
At Muskoka, one hundred and thirty-one miles north of Toronto, is situated the only division point on this line. At present it consists of a railway division yard, a small village of a dozen houses, railway station, round-house, machine shop, coal chute, etc., and a railway-owned-and-operated electric light plant and waterworks system.

In 1907 this district was uninhabited forest and when the new townsite was laid out under Mr. F. S. Darling, M. Can. Soc. C.E. Division Engineer, in charge of construction, the first work to follow the grading was the construction of a sewer.



Surveys showed that the most suitable sewer to build would average ten feet deep through some seven hundred feet of Laurentian granite.

The work of digging the sewer was ordered to go ahead in the middle of July, 1907, and as the erection of necessary buildings for the yards could not be proceeded with until the sewer was completed, because of the blasting, the work was opened up in four places at once and four gangs kept busy until the work was nearly completed.

Continued dry weather made it possible to work to grade at the upper end of the sewer before the lower end was open so that work was commenced simultaneously at stations 0, 6, 8+50 and 11+50 at the same time.

The material from station 8+50 to 11+50 was wasted between stations 11+50 and 15+50, and from station 8+50 to 7, thus making this haul very short but the material from station 0 to station 6 had to be hauled about 1,500 feet, i.e., to the south end of the yards.

This material was broken by dynamite in the trench, mucked into skips and hoisted by horse-derricks upon horse-cars which ran on 30-pound rails.

The profile will show fairly well that there was about 550 feet of sewer 9 feet deep in granite rock and 350 feet about averaging 4 feet deep with a stripping of 2 feet of earth.

A close measurement of the work gave the following quantities :

Common excavation	950 cu. yds.
Loose rock	30 cu. yds.
Solid rock	1,850 cu. yds.

From the following calculations the common excavation and loose rock are eliminated as the cost of that work was kept separate.

The complete cost for 1,850 cubic yards of solid rock was as follows:

			Per cu. yd.
Superintending—			
Walking boss, at 60c per hour	$222.45	or	12.0c
Clerk and timekeeper, at 37½c per hour	158.60	or	8.5c
Foreman, at 45c per hour	608.15	or	32.8c
Total for superintending per cu. yd.			53.3c
Labor—Mucking, loading, hauling and dumping—			
Laborers, at 20c per hour	$2,877.00	or	$1.555
Teamsters, at 21c per hour	499.70	or	.270
Teams, at 40c per hour	1,010.60	or	.545
Cars, at 5c per hour	117.00	or	.063
Carts, at 5c per hour	65.50	or	.035
Derricks and power, at 15c per hour	175.50	or	.095
Handy men, at 27½c per hour	125.15	or	.067
Total for labor per cu. yd.			$2.630
Drilling rock—			
Foot drilling, at 30c per ft.	$1,245.00	or	0.673
Sharpening drills, at 27½c per hour	250.80	or	.135
Nippers, at 17½c per hour	382.20	or	.206
Coal, at $10 per ton	29.00	or	.157
For drilling per cu. yd.			$1.171
Explosives—			
Electric fuses			$ 95.95
Caps and fuses			23.20
Batteries, rent			38.00
60% dynamite, at $10 per box			1,020.00
Or 0.636 per cubic yard.			$1,117.15

Making a total of $4.97 per cubic yard.

To this must be added an amount for the depreciation of plant, in this case $930. This included broken and wasted material and drill steel sharpened away.

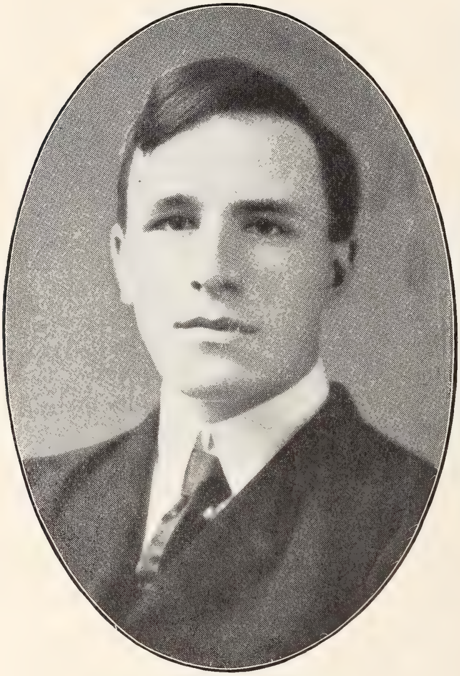
This was equivalent to 50 cents per cubic yard and made a grand total of $5.47 per cubic yard. When it is remembered that it was rock work where the wear and tear upon plant was great this amount is not unreasonable.

This price, i.e., $5.47 per cubic yard for solid rock, is high, but the trench was for 18-inch pipe; it was not wise to use large shots and the amount of drilling, i.e., one foot for 4½ cubic yards, was excessive. The price is not high for trench work in rock.

SAVING WASTE IN MANUFACTURING—A FIELD OF WORK IN WHICH THE TECHNICAL GRADUATE MIGHT WELL LOOK FOR A FUTURE.

J. C. ARMER, B.A.Sc.
Editor of the Canadian Manufacturer.

The technical graduate when seeking a job usually adopts the line of least resistance. Upon graduating few of us can afford to twirl our thumbs until our chosen job turns up. We usually are inclined to take the first good position that we can get. Circumstances usually have more to do with the character of our first job than our own plans and aspirations; and our first job has more to do with our second job than any other influence.



J. C. Armer, B.A.Sc.,
Editor, "Canadian Manufacturer."

This is why we see so many technical graduates in certain lines of industrial life and so few in certain others. It is to the advantage of the technical graduate to have as many fields of industrial life open to him as possible — to have many lines of little resistance and few of great resistance.

The Technical Graduate and the Manufacturing Industry—There will be in the future a closer bond of union than has been in the past.

The manufacturing industry in Canada (except what might be termed the purely engineering part) has been, for the most part, behind a closed door as far as the technical graduate is concerned. There is more than one reason for this; and probably every man one might consult on either side of the door would give a different reason, and most of these reasons might be correct. Being a technical graduate myself, and also having been brought into close touch with the manufacturing industry during the past six or seven years in a capacity which led me to study this very question somewhat, I realize a few of the conditions

that prevent the door opening wider. Of course everything centres more or less around the fact that neither side fully realizes the possibilities of the other. That is the root of the evil.

I believe that the co-operative engineering course, that has been established at the University of Cincinnati, in which the student spends alternate weeks in the college and in different factories and shops in the city, is a part of the solution of this problem. The Faculty of Applied Science, I think, will come to it sooner or later. I know "the powers that be" are watching the experiment in Cincinnati with very keen interest.

In this connection the Executive of the Engineering Society are to be congratulated upon the idea which they carried out at their annual dinner in January; but it is to be deplored that the Board of Governors at the same time let slip such an excellent opportunity of establishing a better understanding by the manufacturers of the work the Faculty of Applied Science is doing through the new mechanical laboratory.

That there is a broad field of work in the manufacturing industry for the technical graduate need not be doubted. A few manufacturers in Canada are realizing it, and are employing technically trained men in positions heretofore held only by men who had spent the better part of their life at the work. The object of this article is not, however, to discuss this subject in general, but to bring to the reader's attention one line of work in the manufacturing industry for which a technical graduate—a student—a man who is trained to bring together cause and effect—is eminently fitted.

The "Saving of Waste in Manufacturing" is a field of work eminently fitted for the technical graduate.

This line of work is the "Saving of Waste." Not a very high sounding title, is it? "Quite beneath the aspirations of an ambitious technical man," some may exclaim; "he wants to construct —to build—not to save;" but before the reader jumps to a hasty conclusion, let him study the trend of modern industry—let him put his fingers on the pulse of modern manufacturing—and he will realize that the "Saving of Waste" is to be the most absorbing science on this continent at no very distant date.

Every one is more or less familiar with the remarkable strides which have been made of late years in the saving of waste in materials, but very few realize the waste which is bound up in the human element — the waste due to the inefficiency of workers. The technical student puts in most of his time studying materials, so that he can classify them, select them to advantage and get the greatest efficiency from them; and practically no time is given to the study of human nature—we have no data collected, no formulas with which to work; yet the real saving of waste in manufacturing has to do more largely with the human element than with the material or the machine.

Evidence of the possibilities there are of increasing the efficiency of workmen in the manufacturing industry.

At one time I operated a planer beside a red-headed Irishman in a certain railway machine shop. This Irishman was running a big slotter. Very many of his antics were very interesting and amusing, but the one that interested me most was his unfailing practice of first removing his overalls, and then stopping his machine, from fifteen to twenty minutes before time. That fifteen or twenty minutes he spent either huddled over his work —to give the foreman the impression that he was adjusting it— or else dodging around his machine to keep out of sight altogether. I wager he did more work in that time than in any other hour and a half. To my queries as to why he shut off his machine so much before time, he would answer: "Well, by the time you have worked as long in the shop as I have, you too will want to get out of as much work as you can." To take off overalls and otherwise prepare for a hasty exit when the whistle blew was natural, although possibly not laudable; but to work extra hard on his employer's time that he might not do the work for which he was paid, even when that work consisted of sitting on a box watching his machine cut the metal, is an exhibit of what the human element may mean in shop inefficiency.

Mr. F. W. Taylor, the author of that world-known paper, "The Art of Cutting Metals," presented to the American Society of Mechanical Engineers as a presidential address some few years ago, who has given more than twenty-five years to the scientific study of efficiency, says of the average workman's potential efficiency:

> "That the first-class man can do in most cases from two to four times as much as is done on the average is known to but few and is fully realized by those only who have made a thorough and scientific study of the possibilities of men. * * * It must be distinctly understood that in referring to possibilities, the writer does not mean what a first-class man can do on a spurt or when over-exerting himself, but what a good man can keep up for a long term of years without injury to his health, and become happier and thrive under."

The inefficiencies in the conduct of workmen which Mr. Taylor, and others such as Mr. Harrington Emerson, have found in a number of places are surprising and most significant. In the rough labor employed in the Bethlehem Steel Company's yards Mr. Taylor found an efficiency of only 28 per cent. Mr. Harrington Emerson determined an efficiency of only 18 per cent. in a gang of laborers excavating a foundation. He has found that the average railway repair shop shows an efficiency of only 50 per cent. He says that in the United States the total amount of preventable material and labor wastes and losses in

railroad operation and maintenance approximates $300,000,000 annually. Harrington Emerson also says in one of his writings:

> "To the efficiency of a process or in the use of a material there is a clearly ascertainable maximum, and when it is exceeded the material gives way, as in the Quebec bridge; but to the efficiency of an individual there is no predeterminable limitation. In the passion for modern scientific accuracy much has been done to solve the lesser problem of efficiency in process or material, but the larger problem of individual efficiency has been almost wholly ignored."

In the face of this, and much more that a little investigation shows the student, does not this field of endeavor, "The Saving of Waste in Manufacturing," stand on as high a level as any other field open to technically trained men, and should not this practically untouched field in Canada appeal very strongly to a number of undergraduates and graduates of the Faculty of Applied Science!

What a few manufacturers in Canada are now doing in increasing the efficiency of their factories by the elimination of waste.

In Canada manufacturers are beginning to realize that immense amounts of money could be saved in materials and labor in their factories and plants; and efforts are being made in some places to effect these savings—the amount of the success depending upon the amount of good, hard study and good common sense put into the effort. I know of a stock room in a Toronto factory in which the manager increased the working efficiency 50 per cent. by a judicious handling of human nature, which, however, is a part of a well founded plan which extends over the entire factory. The manager had no data as to the increase of efficiency over the entire plant, but from figures available one might judge it would be 25 per cent.

The manager of a certain Toronto factory (the Canadian factory of the National Cash Register Co.) owing to a certain exigency was required to decrease the operating expenses of his factory by $12,000 per year, without interfering in any way with the quality of the product or the broad principles upon which the factory is operated. This factory manager was already doing what more than 75 per cent. of managers do in keeping down costs in the factory; and he did not think that he could cut out more waste to the tune of $12,000 per year. However, he called together his heads of departments, including purchasing agent, engineer and foremen, and put the problem straight to them. As a result of co-operation of all hands, this manager now has under way schemes which will save more than the $12,000 per year. This is an indication of what is possible in the saving of waste even when there appears to be no waste.

I might give other instances such as this; and they would

all show the field there is for such work as this in Canada, and what openings there will be for the man who has made a thorough study of systems, organizations and human nature—theory and practice—the man who can go to the manufacturer for a job and in reply to the query, "What can you do?" say, "Well, I can increase the efficiency of your plant by 5 per cent. at least and possibly by 40 per cent."—of course in not quite such a bald manner. An answer such as that would certainly have more effect upon a manufacturer, one way or another, than an answer such as this: "Well, I can operate a planer, do some work on a lathe, and I think I understand Hirn's Analysis"—not meaning any disrespect to Hirn's Analysis.

What the technical graduate may expect in the way of remuneration in this field.

As to salary—the efficiency engineer in the United States who has accomplished things does not have to wear last year's hat, unless he wants to. From the nature of the work done it stands to reason that good salaries can be demanded. For instance, if in a factory employing 200 men at an average of $2.50 per day the individual efficiency were increased by 5 per cent., the saving in one year would be:

$$200 \times \$2.50 \times 300 \text{ days} \times \frac{5}{100} = \$9{,}000^{*}$$

or if the efficiency were increased 40 per cent., the saving in one year would be:

$$200 \times \$2.50 \times 300 \text{ days} \times \frac{40}{100} = \$72{,}000^{*}$$

The man who accomplished this could of course collect from it a salary that would look fairly large to the average engineer.

This field of work contains its share of necessary preparation, hard work, drudging, keen grasping of causes and effects, close study of present methods, a keen study any analysis of human nature, a continual collecting of data, etc., all this based upon a good sound technical training at college.

As to what the Faculty of Applied Science might do towards preparing a man for such a career, much might be said, but at the present moment one feels that it is bad form to suggest further burdens for the Faculty of Applied Science unless at the same time he comes prepared to pry open the treasure chest guarded by the governing powers, in which there may be a treasure and yet there may not.

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* This method of figuring the saving is not correct, but the results are near enough for illustrating the point.

THE ACTION OF FROST ON HYDRAULIC CEMENTS—CONCRETING DURING FREEZING WEATHER.

ALFRED E. UREN, B.A.Sc.
Editor Canadian Cement and Concrete Review

In Canada and the Northern American States, where the effect of frost during the winter season is a more serious question than it is in many European countries, numerous experiments and investigations have been made to determine the effect of freezing temperatures upon hydraulic cements. The writer has endeavored to outline in this article some of the more important investigations made by various authorities along this line, as well as to call attention to the more common methods employed in practice of mixing and placing concrete during low temperatures.

Alfred E. Uren, B.A.Sc.

While the conclusions of different experimenters are not in perfect accord, from practical experience as well as from laboratory investigations, it is now generally accepted that the ultimate effect of freezing of Portland cement concrete is to produce only a surface injury. While experiments have proven that the setting and hardening of Portland cement concrete is retarded by freezing, and the strength at short periods lowered, still the ultimate strength appears to be but slightly, if at all, affected. Mr. Sanford E. Thompson, consulting engineer, is authority for the statement that neither in practise nor research has he ever discovered a case where Portland cement concrete or mortar, laid with proper care, has suffered more than surface disintegration from the action of frost.

While authorities on the subject of concrete, in general, agree that concrete work should be avoided as far as possible during frosty weather, as it is much more difficult to mix satisfactorily and to place materials under these conditions, still if circumstances warrant this added expense, with proper precaution and careful inspection, mass concrete may be laid at almost any temperature. The proper precautions necessary to insure satisfactory results for work laid in freezing weather depend upon the class of work, heavy mass concrete not requiring the same care and protection as light reinforced construction. The subject, in so far as light work is concerned, is summed up in the words of Mr. W. J. Francis, consulting engineer, Montreal: (Paper read before the Canadian Cement and Concrete Associa-

tion March, 1909.) "Do not erect light building work in reinforced concrete during freezing weather. If you are compelled to do so, be careful. It can be done but it means money and eternal vigilance."

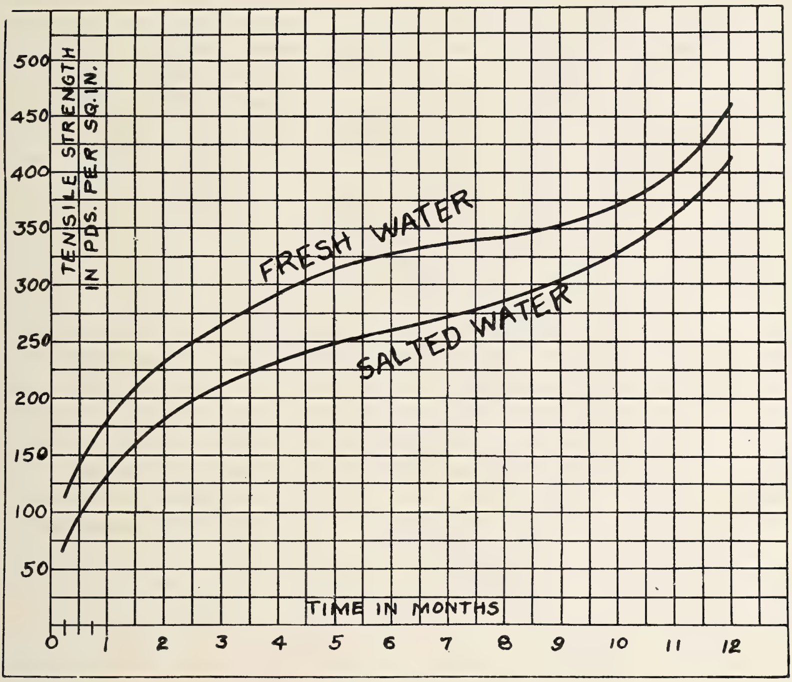
A word of caution against the growing disregard of, and apparent indifference to, the importance of properly placing and protecting concrete work in freezing weather is not out of place. The practise of mixing, placing and caring for concrete work during winter weather in the same manner as in warm weather is, of course, to be condemned. The satisfactory results usually obtained during the winter months with Portland cement concrete serve as an incentive for increased activity and encouragement for carrying on concrete work under unfavorable weather conditions.

It is generally understood that concrete, frozen before the action of hardening has started, is not apt to be injured, if upon thawing, it is not again frozen until it has had a chance to harden sufficiently to withstand the action of subsequent freezing. The alternate freezing and thawing, which allow the intermittent action of hardening, are the conditions to be avoided. In laying concrete the surface freezes unless measures are taken to prevent it. It is well known that a thin crust, about one-sixteenth of an inch in thickness, is apt to scale off from granolithic or concrete pavements which have frozen before hardening. This leaves a rough instead of a trowled wearing surface. The effect upon concrete walls is sometimes similar.

As regards natural cements, they are particularly susceptible to serious injury from frost, especially by alternate freezing and thawing. Certain cases have been sighted where natural cement mortar has been laid in freezing weather with no serious results; there are, however, numerous examples where complete failure has been brought about. Mr. Sylvanis Thompson (see Concrete, Plain and Reinforced) has observed, that after several years, natural cement mortar was but slightly better than sand and gravel. These results were observed by him in the case of natural cement mortar laid during the comparatively warm winter of North Carolina, on days when the temperature was considerably above freezing at the time of laying, and also in the cold climate of Maine where the mortar froze as it left the trowel, without thawing before the spring season. Settlement of masonry when thawing is often a serious characteristic of natural cement. Occasionally tests are recorded in which natural cement mortars have after a time, attained full strength, in cases where they have been subjected to a uniformly cold temperature and then suddenly thawed. However, in view of the fact that there is some doubt on the subject, the investigations made are sufficient to warrant the use of a true Portland cement when frost is likely to occur during erection work, or before the mortar has thoroughly dried. Natural cements are but little used in Canada at the present time for construction work, nevertheless

it is of interest to make these comparisons between the action of Natural and Portland cements.

Several methods are employed in practice to overcome effects produced by low temperatures. The following are those most commonly employed: (1) The addition of a chemical or chemicals that lower the freezing point of the water. (2) The application of heat to the aggregates. (3) Protection of work, by enclosure, etc. In the first instance, common salt (sodium chloride) is commonly used. Calcium chloride is sometimes used as experiments indicate that if used in quantities not exceeding 2 per cent. of the weight of the cement, it is an effective agent for lowering the freezing point of concrete. It should, however, be



used with caution, since a larger quantity than this is likely to so hasten the set as to make the concrete difficult to handle. Other materials, such as alcohol, sugar and glycerine, have been employed in an experimental way. It has been found, however, that they have a tendency to lower the strength of the mortar. Specially prepared liquids and patented compounds have been placed on the market for the purpose of lowering the freezing point, in some instances with considerable success. These are usually dissolved in the water used for mixing. Salt is claimed by some to be detrimental to reinforced concrete, claiming that salt and air corrode steel and that even where steel is not present,

concrete is likely to become somewhat porous. These advocate mechanical means entirely where both moisture and heat should be provided.

As regards the percentage of salt to be added, authorities differ slightly. One method is to add to the water, one per cent. by weight of salt, for every degree Fahrenheit below the freezing point. One authority gives 8 pounds of salt per barrel of cement as sufficient, even in the coldest weather. Others recommend 1.06 pounds per cubic foot of cement. Ten pounds to every barrel of water used, is recommended by one authority.

An original method employed by some consists of adding sufficient salt to the water to give a 12 per cent. solution. A potato has a specific gravity of about 1.08. A 12 per cent. solution of salt and water has a specific gravity of 1.082, a solution which will float a potato. This method is sometimes employed in gauging the density of the salt solution. A 9 per cent. solution by weight of salt to water, was used in the construction of the New York Subway in 1903. On the Wachusett Dam, during the winter of 1902, four pounds of salt were used to each barrel of cement. For a 1 to 3 mortar this corresponds to about 2 per cent. of the weight of the water. Mr. Sanford E. Thompson has adopted the arbitrary rule of two pounds of salt to each bag of cement, to be used when the temperature is expected to fall several degrees below freezing, and if experience shows that this is not quite sufficient to prevent the frost catching the surfaces, three pounds of salt per bag of cement are to be used instead.

The accompanying curves plotted from experiments made by Mr. Chas. S. Gowen, extending up to one year (Proceedings American Society for Testing Materials, 1903, p. 393) show the effect, at laboratory temperature, of 10 per cent. of salt on a 1:3 Portland cement mortar, also that of fresh water.

Perhaps the more preferable method and one commonly employed, consists in mixing warm sand and stone with the cement and water, in such a manner as to bring the temperature of the entire mixture to about 75 degrees Fahr., protecting it from the air during the early stages of the setting. The water may be also heated. In the erection of a building for the Foster-Armstrong Co., Ltd., of Rochester, N.Y., the water was heated to about 90 degrees Fahr., and salt added in a proportion of about 1.06 pounds per cubic foot of Portland cement. The method of heating the water consisted of passing live steam through perforated pipes in storage tanks, and the sand and gravel were heated in the storage bins by means of steam pipes and hot air pipes. As each part of the building was constructed it was housed in by a temporary structure of timber and canvas, the open sides being enclosed by canvas curtains. The space enclosed by this housing was heated by coke fires and braziers, and by means of steam pipes from a central boiler, live steam being discharged into the spaces between the housing and the concrete.

The temperature in the enclosed spaces was kept at about 80 degrees Fahr., below the floors, and about 40 degrees Fahr. in the spaces between the top of the floor and its board covering.

Mr. J. H. Chubb, Assistant Inspecting Engineer Universal Portland Cement Co., Chicago (Bulletin No. 56, January, 1909) states that "Salt should be used only in plain concrete work, as its effect on reinforcing metal has not been established. Even when salt is used it is important that the aggregates be free from lumps of frozen material, as it is impossible to properly mix such materials. Approximately one per cent. by weight of salt to the weight of the water is required for each degree Fahrenheit below freezing, but more than ten per cent. of salt should not be considered safe and this amount is not effective for temperatures lower than twenty-two degrees Fahrenheit. The best method of concreting in freezing weather is to heat the materials and to protect the work until it has obtained sufficient strength to withstand the action of frost. Either the water, sand and water, or sand, stone and water should be heated. The cement is usually not heated. Heating the materials accelerates the rate of hardening, lengthens the time before the material becomes cold enough to freeze, and in temperatures but little below freezing will insure the hardening of the concrete before it can be damaged by freezing. For heavy mass work, thick walls, abutments, etc., it is not necessary to heat the stone except in exceptionally cold weather, but sand and water should be heated. If the forms are tight and made of heavy material, it will only be necessary to protect the top of the work; this may be done by covering with a canvas and running steam under it, or by covering with boards or paper and applying a covering of straw or manure. If such work is protected from freezing for several days it is sufficient, unless it has to be loaded immediately, but thin walls, light foundations, etc., should be protected on all sides in the manner pointed out above. For reinforced work it is necessary to heat all the materials but the cement, and the concrete should be hot when placed in the forms, and where the work must be placed into service as soon as possible, the only safe practice is to keep the surrounding temperature well above the freezing point until the work has thoroughly hardened. Concrete increases in strength but very slowly in cold weather, and for this reason forms should be left on as long as possible, and care taken not to load a structure too soon. Just how old the work should be before removing the forms and subjecting it to its load cannot be stated, as this will depend entirely upon how fast the concrete hardens. Careful inspection of the structure is necessary before removing the forms and applying the load, and it must be remembered that frozen concrete, which upon thawing has but little strength, closely resembles thoroughly hardened concrete in appearance, and when broken frequently shows a fracture through the aggregate. All classes of concrete work, with the

exception of walks and pavements, may be constructed in freezing weather, but to insure satisfactory results proper precautions are necessary, which will entail an additional expense, depending upon the class of construction and importance of the work."

Engineering News (Vol. XLIX, No. 12) contains an article by Geo. W. Lee, where a combined water, sand and stone heater was used successfully. It was erected at a cost of fifty dollars and weighed about twelve hundred pounds. Considerable concrete work on the construction of Hurdman's Bridge, Ottawa, was carried on when the temperature was as low as 12 degrees below zero. In this instance the materials were partly heated, and partially protected with canvas cover after being deposited. A first-class concrete was produced. Engineering News (Vol. XLIX, No. 19) contains a description of the construction of a concrete dam at Chaudiere Falls, Province of Quebec. It was found necessary to construct a portion of this work during the winter months when the temperature ranged all the way to 20 degrees below zero.

The action of frost on Portland cement mortar and neat cement has been extensively investigated in an experimental way. A series of interesting experiments by Ernest R. Matthews, Borough Engineer of Bridlington, England (Volume XXXV, proceedings of the American Society of Civil Engineers) give in detail the action of frost on cement and cement mortar, together with other experiments on these materials. These investigations were made for the purpose of ascertaining, among other things, the effect of frost, and alternate frosts and thaw, on the tensile strength of cement and cement mortar when mixed with cold or warm water, also the temperature below which it is detrimental to mix Portland cement concrete. The cement used was manufactured by Robson's Cement Company of Hull, England, and conformed to British standard tests. These investigations led to the following conclusions:

(1) That light frost occurring 24 hours after the cement has been gauged (3° of frost, or thereabouts), is detrimental to freshly mixed Portland cement, but only for a short time, and that at the end of 28 days it has quite regained its normal strength. If the frost occurs immediately after the cement has been gauged, the effect is more detrimental, and would appear to be permanent. A minimum quantity of water should be added in frosty weather.

(2) That heavy frost (17° of frost, or thereabouts) has a most injurious effect (permanent) upon freshly mixed cement (neat), and cement mortar.

(3) That a light frost (3° of frost, or thereabouts) does not affect cement or cement mortar if it has attained two days' set previous to the occurrence of the frost.

(4) That the detrimental effect of light frost upon cement mortar (3 to 1) occurs more immediately than upon neat cement,

but that cement mortar recovers from the ill effects of frost more rapidly than neat cement. At the end of 14 days it has quite recovered.

(5) It would appear that it is detrimental to concrete to mix it when the temperature is below 29.3° F. (2.7° of frost), that being the freezing point of cement and concrete.

An extensive series of experiments conducted by Mr. Thomas F. Richardson at the Wachusett Dam in Massachusetts, extending up to one year, were sufficient to conclude that Portland cement mortar is not permanently injured by freezing. These experiments were conducted in the middle of the winter. Two bags of Portland cement were thoroughly mixed together and all the briquettes were made from cement taken from these bags. These experiments were carried on while the masonry work on the dam in question was in progress. The briquettes that were tested were made each week and submitted to the same conditions as the masonry, the moulds being placed in the open air and not in water, immediately after filling. At the same time briquettes were made that were kept in the laboratory. Those out of doors were exposed to temperatures as low as 9 degrees above zero during the first 24 hours, and some to temperatures as low as 12 degrees below zero during the first week. Salt ranging in quantity from 4 to 16 pounds per barrel of cement was used in most of the experiments (the average being about 3 per cent. by weight of water). These experiments indicated that 8 pounds of salt per barrel of cement is sufficient even in the coldest weather, that 4 pounds is very nearly as good but that 16 pounds does not seem to give quite as good results. The following table, which gives the average results of these experiments, shows the effect of frost upon the tensile strength of a 1 to 3 mortar mixture:

Briquettes Kept.	No. of Briquettes	Tensile Strength, lbs. per square inch.				
		7 Days	28 Days	3 Months	6 Months	1 Year
Water in Laboratory....	20	268	304	359	370	401
Air in Laboratory......	20	298	352	364	392	517
Out doors, below freezing	80	139	238	344	435	627

Table showing the effect of frost on the tensile strength of a 1:3 mortar mixture.

During 1901, interesting and valuable experiments were conducted at the Watertown Arsenal, U.S.A., to ascertain the effect of low temperatures upon the strength of cements and cement mortars, the results of which are given herewith. For a complete description and results of these experiments see "Tests of Metals," U.S.A., 1901, page 530, from which these results were taken. A part of these experiments consisted of placing groups of cubes in a cold storage warehouse, where some of them were subjected to a temperature of 39° F. and some to a temperature

of 0° F. Those subjected to the lowest temperature were mixed and moulded in a temperature below freezing. All cubes were subjected to the tabulated temperature as soon after mixing as practicable, and before being tested were kept at a temperature of 70° F. for the number of days indicated. Herewith are tabulated some of the results on cubes composed of a 1:1 Portland cement mortar, gauged with 16% water for the group subjected to 0° F., and 12% water for the other group.

EXPERIMENTS CONDUCTED AT THE WATERTOWN ARSENAL TO DEMONSTRATE THE EFFECT OF LOW TEMPERATURE UPON THE STRENGTH OF CEMENTS AND CEMENT MORTARS. THE AVERAGE COMPRESSIVE STRENGTH OF FIVE CUBES IS GIVEN IN POUNDS PER SQ. IN.

Days at 0° F.	Days at 70° F.	Strength.	Days at 0° F.	Days at 70° F.	Strength.	Days at 39° F.	Days at 70° F.	Strength
5	1	287	5	7	846	15	0	1710
14	1	321	14	7	1000	31	0	1960
21	1	337	21	7	1010	60	0	2460
31	1	383	31	7	981	15	7	2710
60	1	416	60	7	981	31	7	2720
90	1	497	90	7	1010	60	7	3270

The results of practice and experiment with cements exposed to frost lead to the following conclusions:

1. Most natural cements are completely ruined by freezing.
2. Frost expands natural cement masonry and settlement results with the thawing.
3. The ultimate strength of Portland cement in mortar or concrete is but slightly, if at all, affected by freezing, although its setting and hardening is retarded and its strength at short periods lowered.
4. Heating materials hastens setting and retards the action of frost.
5. Salt lowers the freezing point of water and does not appear to affect the ultimate strength of the concrete or mortar, if added in quantities up to ten or twelve per cent. of the weight of the water.
6. A thin scale is apt to crack from the surface of concrete walks, walls, etc., if frozen before the cement has hardened.
7. Concrete work, if possible, should be avoided in freezing weather because of the difficulty and expense of attaining perfect results.

RECENT ADVANCES IN ELECTRICITY.

CLARENCE E. BOTHWELL
Associate Editor Canadian Electrical News

Ninety years ago electricity was defined in an American text book as that property in bodies in virtue of which, when rubbed they attracted substances and emitted fire, and even as late as fifty years ago this might have represented the popular knowledge and conception of things electric. The slow evolution which has transpired is not unnatural and in dealing with electrical science, history has but repeated itself. Throughout all ages the progress of any change destined to be of world-wide importance has always been notoriously retarded. The disconnected theorem of the scientist must first be given to an unheeding public. Perhaps a few generations later these same principles are embodied, through the genius of the inventor, in a device which constitutes a distinct advance in commercial progress. The next step is to secure the adoption of the invention by a sceptical industrial public. In this sphere radical departure from methods of accepted procedure always have met with deep-rooted opposition, and at the best only a modification of the device in hand is accepted. Once, however, the confidence of the industrial world is obtained the appliance of meritorious value makes rapid strides.

We find that the fundamental principles of electricity were exploited by eminent physicists years before they were turned to commercial account, and the invention of electric machines received but scant attention until many years after their preliminary investigation and actual commercial establishment. Twenty-five years ago incandescent lamps were an advertised feature of industrial exhibitions and were considered a freak rather than a factor in the country's development. The changes within the last decade have indeed been wonderful. Electricity and progress are interchangeable synonyms and the world recognizes that mostly all recent accelerations of modern business conditions are the achievement of the electrical engineer.

In the operation of industrial establishments, electrical power is forcing recognition as an important factor. Its entrance to this field is not of long standing. First, came its use in an auxiliary capacity for the operation of special or isolated machines and gradually upon its merits it superceded other forms of power for factory operation. To commend it were many striking qualities: Its absolute cleanliness; its adaptability to the closer speed regulation of modern high-grade machines; acceleration of output, which the perfection of the high-speed motors made possible; the economy of space afforded in the system of power distribution over other more mechanical methods; its cheapness, where water power is available, compared to other methods of operation.

To enumerate the every-day uses of electricity, all of which have had their place in the world's industrial progress would entail a needless repetition. To mention the myriads of opportunities for its application would be impossible. Wireless telegraphy with its more or less widespread use is but in its infancy. Marine electrical propulsion has been receiving serious attention and for some years has been quietly asserting itself as an art and an industry. The propulsion of ships was one of those greater power applications of electricity which were necessarily delayed pending the perfection of a means of generating large quantities of electrical power cheaply, but the recent advances in design, construction, and operation of the steam turbine and gas and petroleum engines has brought the successful consideration of this problem within sight. At this distance it would appear that electrical transmission of power offers the solution to the ideal slow-speed propeller and a reduction in weight and capacity of the boiler room through the economical operation of the prime mover.

The achievements of electricity in the realm of the newspaper are none the less noteworthy and give every promise of facilitating the movements of this important branch of the industrial field. In the printing shop, the introduction of proper driving motors and controlling devices may be looked for which will revolutionize the art of printing. A striking instance of progress may here be noted. Not long ago the London, England, "Evening News" was enabled to print verbatim a speech delivered by Lord Rosebery in Glasgow, and to have its edition on the streets in London before the speaker had left the hall in Glasgow. This wonderful feat was accomplished through the instrumentality of the electrophone—a specially constructed and extremely sensitive telephone, devised by an Italian scientist.

The growth in demand of electricity for power purposes has led to the adoption of larger generating units and as a consequence, in recent years the trend of manufacturers of electrical machinery has been to show a remarkable progress in the utilization of materials, and in their later machines they have managed to show a larger output in proportion to the quantity of materials used. The demand for larger units has thus been met and it has facilitated the distribution of power over a larger area and at higher pressures. The invention of the suspension type insulator has materially assisted in the design of high potential circuits and shortly we will see placed in operation the 110,000 volt line of the Ontario Hydro-Electric Power Commission, an engineering construction that in magnitude of projection will for some time remain in isolated grandeur.

One cannot but feel that this is the age of electricity and that Canada will have a large share in the gradual uplifting of the industrial efficiency of the world. When the existing power companies and companies of the future have taken full advan-

tage of the magnificent water power resources of this country, the day should not be far distant when a closely woven network of electrical wires will furnish the smallest and the largest centres of this country of ours with all her power requirements for industrial, commercial and agricultural purposes.

The present day electrical engineer must be a broad man. First and foremost, he must be a Booster, a full-fledged member of the Boost Club. His motto shall be: "All together all the time for everything electrical."

The engineer must also be a business man. He must be a firm believer in advertising. Engineers take too readily for granted that the general public are familiar with all the advantages and developments of electrical power. As a rule the public are extremely ignorant in matters pertaining to electricity, with the exception, perhaps, of the electric railway problem.

Above all else the engineer should be an optimist—believe firmly that the demand for electrical power will grow rapidly; encourage a customer to instal a machine larger than his present day requirements; your load-factor may suffer, but do not lay too much stress on this; be big enough to drive through it. Later on, the chances are that this customer will add to his load and thus increase your power-factor. With a small motor connected in, he will over-load and troubles from short-circuiting may frequently be expected.

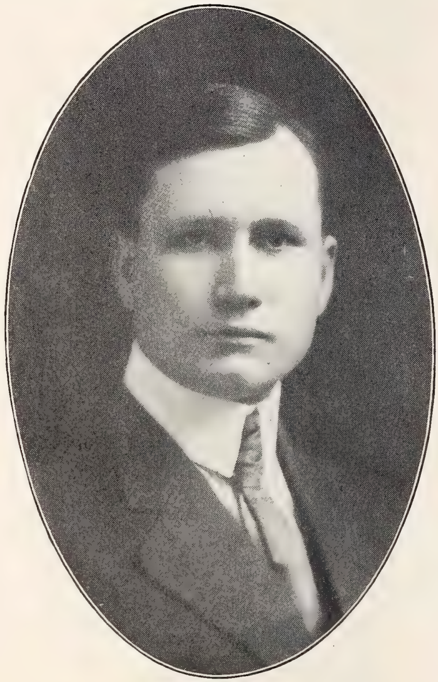
Lastly, to facilitate electrical progress, engineers must co-operate, not only in the collection of technical data but in the furthering of the general electrical interests. For instance, we should learn a lesson from the experiences of the Ontario Hydro-Electric Power Commission regarding the question of easements for power lines.

We cannot expect to obtain general improvement to the law with regard to easements for overhead lines until a strong case is made out, by the collection of data from all interested countries, showing the present disadvantages suffered. This example is one of many, but will serve to show the urgent necessity for co-operation amongst members of the electrical fraternity.

INDUSTRIAL EDUCATION.

K. A. MACKENZIE, B.A.Sc.
Managing Editor, Applied Science.

That Canada has at length awakened to the advantages and necessity of Technical Education can no longer be doubted. The speech of J. P. Murray, in the February "Applied Science," shows that our manufacturers have been and are giving the matter considerable thought. Technical Education may be roughly said to treat of the application of the principles of science and art to the agricultural, industrial and commercial interests of the country. Before going into the question it might be well to discuss briefly the history of education, keeping always in view that a school education must not only prepare a student for life but also to make a living.



K. A. Mackenzie, B.A.Sc.

The only education in book form which survived the Dark Ages was held by the monks. As years went by, they disseminated what learning they had to their successors and, in homeopathic doses, to the lay population. They appreciated that in book learning lay a power worth preserving. Other learning, the knowledge of crafts and practical knowledge was passed by word of mouth, precept and example from father to son; from master to apprentice; never gathering momentum because there was no literature to preserve and collate its mysteries. Thus it is that some of the practical industrial secrets of the ancients have been lost to the world for long ages.

In those early days began that mutual contempt between the practical, represented by the guilds, and the theoretical, represented by the monks. The latter dominated through the power of logic, from the accumulated philosophy of centuries, over the limited, self-centered and self-sufficient secrecy of the trades. The advantage then gained has made itself long felt and this monk-made education is still dominating our educational systems. It gave us the dead languages, mathematics and phil-

osophy; but it barred from the schools and from the world their practical application.

This was the state of book learning at the time when technical schools were first established. The founders of these schools were in many cases hard-headed men of affairs with large faith in the schools they proposed and small idea of how to accomplish their purpose. These men expected these schools to turn out men skilled in trade; men who should become leaders of men. Since they were to be schools what more natural than that they should engage men from other schools—that is, colleges—to lead them, and what was more natural yet than that these same men should make these technical schools what they are, merely schools with technical leanings. The technical school product thus necessarily failed as practical workmen, but soon evolved into competent designers, engineers and leaders. This was quickly seen and they immediately disdained the very product which they were originally engaged to make. They began to change their schools into engineering schools, which change is at the present day nearly complete.

The graduates of the technical schools aroused the jealousy of the man educated in the shops. The shop trained man had manual dexterity and if he added native ingenuity and mechanical interest he succeeded. The school man had mechanical theory and trained method of reasoning and, if added to this he had a native ability to understand shop processes, he too succeeded; in time, ability being equal, out-distancing his competitor, but those who acquired the necessary dexterity did so only at an expense of time entirely out of proportion to the results gained.

The first attempt to provide skilled workmen having failed, manual training was hailed as the succor needed. Manual training has done all that its real projectors expected but nothing at all of what its later advocates claimed.

Now the trade school movement is having its boom. All over the country there is quite a movement in favor of trades for the younger generation. The barriers between the theoretical and the practical are breaking down. Soiled hands are no longer regarded as not creditable. The pendulum is now swinging the other way, recognizing the usefulness and dignity of the man who makes things. All men cannot be engineers and professional men. From the people, however, comes a demand that there shall be an opportunity for their sons to learn to work with their hands to the best advantage. From the manufacturer comes the demand for educated and resourceful workmen, from the country comes the cry for conservation of all of the raw materials, that of labor included.

The low efficiency of the workmen in various trades in Canada is becoming a cause of concern, not only to the employers and owners of industries but to the leaders of organized labor as well. The present day tendency for specialization has made it well nigh impossible for apprentices to get a good general

knowledge of their trades such as in former years was quite possible.

It has been noted, however, that workmen coming to this country from Germany are better all round workers than the average man in the same occupations.

It would be interesting to note the reason of this. In Germany, all children are compelied to attend the ordinary culture schools till they reach the age of fourteen. In these general culture schools they receive also manual training exercises intended for general education. In the "continuation" schools, the instruction is by skilled mechanics and tradesmen. In them one may learn to be a bricklayer, a carpenter, a blacksmith, and so on, receiving a thorough two years' trade school training by experts in the trade.

This system could be easily incorporated into our Canadian educational system. We need similar vocational schools that we may prepare our young workmen to be more efficient workers, more skilful and less wasteful. For years the province has been spending money on general culture and higher technical education with no corresponding outlay for those, and they are the vast majority, who cannot attend school past their fourteenth or sixteenth year.

However, the system could be advanced still further. Hand in hand with our high school system, we need a further, more advanced class of vocational schools for students who have completed their general culture-high school course at the age of eighteen and wish to spend not over two years in becoming proficient in one of the more advanced trades. In these higher vocational schools could be taught occupations such as lithography, printing, machinist, and so on.

This vocational training would not interfere with the manual training which is now given in our high schools and which would be continued as general cultural education, to students in all courses, so that they may have trained eyes and hands, with a knowledge of the arts and crafts in general.

By this arrangement we have provided for the students who cannot go to school beyond the periods of primary and secondary education respectively, by giving them an opportunity in separate schools, to gain vocational training. At the same time we have kept the curricula of the primary and secondary schools free from vocational studies and can devote the time to the work that will best prepare for citizenship and for life in its broadest sense and also at the same time retain a section of our secondary schools for such preparatory studies as are needed for entrance to the university, and engineering colleges. Our engineering colleges should also provide courses more strictly along the lines of industrial management.

The greatest demand made on engineering schools thus far by students, their parents, and their employers, has been for technical specialists, and the need will always exist for graduates

prepared to become chief chemists, head electricians, chief draughtsman and designers. But there is also a need for men so trained that they can be developed to fill positions in industrial management. Our industries are at the present suffering from the lack of such men as these—men who are not only thoroughly familiar with productive processes, but have broad human interests and are at the same time thorough business men.

Our captains of industry are recognizing the need of these men, which is a hopeful sign, as it has been proven time and again that any system of technical education is liable to failure unless it is preceded by an active demand from those whom it will benefit.

In the past so large a proportion of our technical graduates have found employment in the large electrical and engineering corporations, that the smaller industries of the country have not availed themselves of the services of technically trained men to any considerable extent. Yet the most wasteful power plants, the most inefficient manufacturing processes, the most uneconomical building arrangements and poorest organization methods are found in the smaller industries.

The young graduate, be he ever so good, and no matter what his course of study has been, will not of course be able to revolutionize matters shortly after his employment in such an industry. Yet he should be able to save his wages many times over, from the beginning, if he has been properly educated.

These men must be trained along three lines. They must be thoroughly grounded in engineering, they must have creative ability in applying good statistical, accounting and system methods to production; and, finally, they must know something about men, possessing some of the innate qualities of leadership, it being presumed it is only the picked men who reach this rung of the educational ladder.

Having mapped out in a slight way the ground of industrial education, the question naturally arises, what parts should the different interests assume in the movement.

The Dominion Government should be the source of information and a centre of dissemination on all questions of technical education to all parts of the country. The United States Department of Labor and the Commissioner of Education perform such an office.

The Dominion Government, which can subsidize a single industry—the steel industry—to the extent of $16,507,200 to develop the raw materials of our iron mines, and its infant industries, should surely be able to subsidize industrial educational to develop the raw material of our labor. A study of conditions in foreign countries shows that the system of vocational schools receives great assistance from municipalities, manufactures and labor organizations. As to the Province contributing liberally there can be no question.

Hon. A. G. MacKay, speaking on technical education before

the Ontario Legislature, urged the province to unite with the municipalities in the establishment of craft or trade schools in the cities and towns to supplement the practical training of the workshop, and effect an arrangement as to the basis of their support among the province, the municipalities and the interested manufacturers. He also urged the establishment in large industrial centres of technical high schools, towards the support of which the municipalities should be empowered to contribute.

It was, the Liberal leader forcefully pointed out, no adequate apology for lethargic action on the part of the province to submit that the Dominion was going to "do something." The Dominion, he had no doubt, would do its part, but the Federal Government was careful to observe the limits of its jurisdiction. Education belonged exclusively to the province. The Federal Minister of Labor was sending out a commission for the purpose of gathering information. It was true that efficient and effective industrial education would enhance the trade and commerce of the Dominion, and to this end it was to be expected that cooperation would be extended. But the responsibility and the opportunity were with the province. He urged the Legislature to be up and doing.

In concluding his address he spoke as follows:

"Let us analyze our system of education. We are generous to the high school and collegiate student; we do not withhold our hand to the normal and model school pupil; we are liberal to the university scholar; we extend practical encouragement to those who are in attendance at the Agricultural College. All this is well. But what about the lad whom chill penury sends to the workshop at an early age? We don't spend a dollar on him.

"Let us be frank and honest with ourselves. Our educational system is poorly balanced. It is a matter of vital importance that this should be remedied. It touches not alone the industrial problem; in the larger sense it affects the ethical side. The State cannot afford to drop these boys. The need of the day is something for the child of the wage-working class.

"This is not a political matter. It is provincial. Neither the old Government nor the present Government have evolved any adequate solution of the problem which confronts us. We mean well enough, but we lack intelligent direction. It is high time to do something."

By all means one of the most important functions for the Dominion Government to take up is the question of **Research**. This could be done by the establishment of a National Research Bureau similar to the Watertown Arsenal, the Structural Material Laboratory at Pittsburg, Pa., and in connection with the different laboratories of the leading American Engineering colleges.

The executive of the Canadian Society of Civil Engineers are now pressing the Federal Government along these lines.

Tuition would be in no part the duty of the Research Bureau. It should be manned by the best men obtainable. Their work would consist in the investigation of our resources, whether occurring directly in nature or as by products in our industries. There are a thousand and one problems awaiting solution. The problem of electric treatment of iron ores, so ably handled by Dr. Haanel, is an example. Many sources of economic waste might easily be stopped and millions of dollars added to the national wealth. On this phase the example of Germany need only again be quoted to show its importance. The difference between success and failure, between partial success and wealth, often lies in the waste heap and the treatment of by-products.

Too much attention cannot be given to the research problem in our universities. In our Canadian engineering colleges we are sadly hampered by the lack of funds and equipment. The possibilities for good by direct results and the training of men capable to carry on further investigation are obvious. In Ontario to-day the problem of sewage disposal is ever pushing itself more into prominence, yet we have little or no definite knowledge as to local problems. It is true that the Ontario Government has established a laboratory in Toronto, but this is being treated more as a bacteriological station than for investigating the problems of sanitary engineering.

The example of the Sanitary Research Laboratory and Sewage Experimental Station of the Massachusetts Institute of Technology at Boston need only be quoted to show the possibilities and the immense advantages to be derived from such a station. In other lines, the work that the Agricultural College at Guelph does for the agricultural industry might be duplicated for the manufacturing industries.

The Faculty of Engineering is the only Faculty of the University of Toronto lacking research scholarships. This hinders the work greatly. The graduates are taking the matter up and promise soon to have a start made.

A movement should be started to keep before the manufacturers the possibilities of research. This might possibly result in a manufacturer or a group of manufacturers providing funds for the maintenance of a fellow whose time would be primarily employed with a particular line of research, but given in part to university work. This plan has worked successfully in the University of Kansas, being introduced by one of our Toronto graduates, Prof. R. Duncan. Its initiation here would give an immense and needed impetus to the work in the University of Toronto.

THE TECHNICAL WHO'S WHO.

PREFACE.

"Applied Science" does not hold itself editorially responsible for the opinions expressed in its papers by authors.

A canvasser has requested Mr. E. C. Easy, C.E.—that walking stress diagram of eminent engineering intellectuality—to join the new social club for technically trained men in Toronto, and desired to know whether the notable expert wished to be fyled away as an engineer, or a surveyor, or an architect; and if the first, what kind of one. There was the rub. Mr. Easy could not make the grade.

The great man was undeniably cross. He unloaded himself on poor, defenceless me. He does not usually employ strong language but he flung everything to the winds on this occasion. He smote his thigh.

"Crumbs!" said he, "Bread crumbs!" With that he blushed.

"Whither are we drifting?" querulously he demanded, his thought-corrugated visage astare at the ribs in the arched ceiling. "Where is our ancient and honorable profession off-getting-on-at? What would Stevenson have thought, what Smeaton said, not to mention James Watt and other foot-rule gentry —the old masters of rare technique who inveigled their pictures into history, as authorized for use in the public schools in Ontario." Mr. Easy shifted his chair and contrived a bow-knot out of his long legs. He was getting wound up.

"I would just like to have glimpsed the dago face of him had *Nonius Datus*, Esq., C.E. (A.D. 152),* the underpaid hydraulic engineer of the Third Legion, been button-holed, as to his *toga virilis*, by my friend the canvasser.

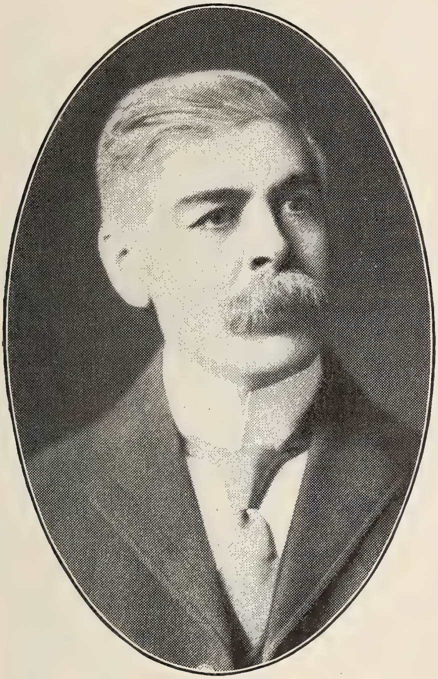
"He said he was a young engineer. He had a viz that looked as if a lot of field rivets had been skipped. But he was oily—slicker than the hair on a Petrolia frog. He was so smooth he wouldn't retain at 50 to 1, and that's agoing some, as they say in the Arithmetic. However, he didn't get mine in his bunch of classy tracing-cloth signatures. This new club is to consist of engineers, architects and surveyors. Do you take me? A dinky triangle of money-needing forces. Now, as proved by laboratory tests, I'd crave to enquire, where's the dividing line, the party wall. When they say engineer, do they mean engineer, or (perhaps it is shown plainer on a section), when is a hen?"

I kept still, perfectly quiet. Mr. Easy—that past master of scientific profundity—was not one to be argued with. Perfect, beatific stillness. The sound like a giraffe gargling was only a water pipe outside.

Mr. Easy resumed. "I s'pose that fat-head canvasser tried

* Dean Galbraith's Valedictory as President of the Canadian Society of Civil Engineers (1909) was evidently surging through a certain brain, which we will designate as "X"

to see would I get rattled; must think I'm chief engineer at a mechanical toy factory—baby rattles a specialty. He is apt to be in the Burke's Peerage of Smart Alecks who would belay you to a street corner and cause you to miss a transfer while he contributed to your already over-flowing think-reservoir the balmy, uplifting hypothesis that hydraulic engineers trek in two brigades—those who work at it and those who drink it. The muzzle legislation should include the likes of him. Wouldn't his pronouncements add to the gayety of nations and merit a floral tribute of price; wouldn't the mover stand a good chance for the chairmanship—he'd be carried out unanimously. Never mind, don't worry, the golden orb will yet rise on a working day of 24 hours when he'll find his own level — also transit. Civil Engineers and impolite surveyors alike are often fain to. And often borrow them—also other articles of a field-work toilet."



C. M. Canniff, B.A.Sc.
(E. C. Easy, C.E.)

"Bug-house! I should so conjecture. Right up to the nth! He'll never turn out any John G. Pocketfiller, or J. Bluepoint Sturgeon, or Lord Skincoona. That's my one best comment. I fully expected him to volunteer that a sanitary engineer is one who may be crazy, but lacks the funds to board at a decent, comfortable Insane Asylum. Oh. Crumbs! Also that a Railway Engineer, if you get on to his curves, is different to all others, because he travels in a special train of thought. How would that hit the genial, sage, and strictly moral architect of a jerk-water stump-dodger? Without the aid of a lens one could discern the palpitating bulges made by pathetic, lost-chord, looney ideas of that character taking exercise in his forehead's back-yard."

"I expected him to tell me that Mining engineers are noted for doing a lot of low-down work, and being experts on the seamy side of life. What? No, that canvasser's got no surcharge of technical fill behind his back. He an engineer!

Crumbs! Crumbs! If he were my assistant for about a minute I'd kink his tape, I'd glue up his slide-rule."

"He'd not be suggesting any more that Roadway engineers should mend their ways; or that a Surveyor's best plan is to make both ends meet when he starts in to callous his elbows over the drawing-board; how would they, for instance, like to be told that surveyors don't work at all—simply are low comedians, playing problem plays at measure for measureable wages? Like as not one of his simpering inanities would be that all engineers, save the stationary fellows, are generally working themselves out of a job. I believe really that that chap could encase a square meal and dreamlessly go to 'bye-bye' after defining a civil engineer as one who made mountains out of mole-hills, and vice versa, each to each; likewise explaining how they were called civil, enjoying as they did a bowing acquaintance with other clans of engineering talent."

"Answer me. Why can a punk applied mechanic like that buy India ink at the same price I pay? Consider not a kid-gloved vernier twister at all—for even a common draughtsman who draws the line at $40 per—making black scratches on white paper—could tear off reams of lunatic specifications like that. Possibly have the decency to accord his face a flat-wash of carmine too. A licensed set square chauffeur doesn't amble forth in the stilly night and imagine himself formed into a scientific brain merger every time he feels chesty enough to buy celery and Roquefort after an evening's close figuring at the Star Theatre or the Gayety. He resembles our University—he's got some reasoning faculties."

"How would a surveyor like to be called a '*Poduk-asin Ashish-kie-ikank*' just because it's Ojibway for 'stick-in-the-mud.' That's the brand of insipid sop his crater would be liable to erupt. He'd be spending that grade of small change like a soused inmate of one of our saucy Canadian Dreadnoughts. It's enough to make a really truly and sincerely engineer hire an aerotaxi and drome away and dee."

There are engineers by profession and those who profess to be engineers. Both amateurs and professionals enter the engineering Marathon. As Peary remarked with that 'welcome-to-our-Polar-City-smile' of his: 'Many are Cooked but a few are frozen.' More probably Peary was considering a human being than cold storage meat. What yer know 'bout dat?"

Now, it is an interesting—to most a likeable—attribute of Mr. Easy, this eminent authority with a strangle-holt on technical wisdom—that one can rarely fathom whither his next thought is trending. In his public or private life one can say, like the girl with steel corsets who learned to run a compass—he has a certain inherent attraction in his surroundings.

"I'll bet a silver-plated protractor as big as a cart wheel," asserted he, "against a rusty pair of spavined dividers that that

pin-head canvasser will suggest to the Chemical engineers a letter-heading along the line of the attached sublime sentiment:

'Little Johnnie's dead and gone,
'We'll never see him more;
'For what he took for H_2O
'Was H_2 SO_4.'

Dot is sense, vot it is, is it? Ach!

"How would an individual who ponders week in, week out, in terms of galls. per sec., or lbs. per sq. in., care to be told that a Mechanical engineer can be identified by the oil he puts in his salad dressing? Would getting caught in a belt like that be a relish? Oh, you kiddo! Would you subscribe to a Structural engineers' being one who approves a rotary mixer rather than every-day Radnor, or an occasional observation of Apollinaris, with its accustomed satellite. Details of the personal character of Electrical engineers, with him, would pass current for juicy. Isn't that joke ripe for its old age pension? Do Elevator engineers make a social pastime—a pay-as-you-enter relaxation—out of the gold cure? Woe's me! I imagine he considers the Architect's function is to take an engineer's plan and dot the i's and cross the t's, and put some curlimagigs on the capitals."

It was at the Engineers' Club that Mr. Easy had unbosomed himself to me as above. Two or three members had joined us in the interval. Then the power went off, the lights went out, and everybody made for the street. As I felt my way down stairs I could catch some drift of a hit-the-bull's-eye definition of an engineer: " a man" (as near as I could gather) "with a quality of brain to figure out beforehand that it's not necessary to turn a horse upside down to get on its collar."

Here a slip on a step, and a quick-fuse, muttered invocation to—sounded like "Happy Hooligan" or "Holy Hexigons." Then a match scratching....a little later, "but that canvasser.... light another match, light two, light a box....his advertisement would read....

" 'Bridges Designed Free.
If not Built
No Harm Done.' "

And next...."Sure! He was *maison du scratch*....them's Penetang French for 'bug-house.' "....Another slip on the stair.... a determined, seismographic, a most tasty one, likewise a flash down below like Halley's comet, then a convulsive "Thank God! Cheer up, here's the door. O, Crumbs!...." When I reached the street Mr. Easy and companions had faded and gone. All was quiet. I found my way and wended it. The new club is determined upon getting the most eminent engineering prodigy of our land and age to join, but it is still on the waiting list.

WHAT THE GRADUATES ARE DOING

This section is conducted with a double object in view—First, to give the graduates professional news of each other; secondly, to give the undergraduates an idea of the possible fields of employment open to them in the future.

Walter Jackson, '07, is with the Ontario Power Co. on the construction of their second conduit.

N. C. A. Lloyd is employed on construction on the Canadian Northern Ontario Railroad on the Ottawa-Toronto line.

R. Pettingill, '06, has been transferred to the Port Colborne plant of the Canadian Cement Co., being in charge of the chemical department.

Frank G. Mace, '05, is employed in the Patent Office, Department of Agriculture, Ottawa, as Patent Examiner.

T. Harry Mace, '05, consulting engineer, Confederation Life Building, Toronto, is taking over the engineering office and business of Baker & Jordahl after being their chief engineer for a year and a half. His specialty is power lay-outs and transmission and reinforced concrete design.

J. F. S. Madden is with the Canadian General Electric Co. at Winnipeg.

K. G. Marlatt is at present in London, taking a post-graduate course at the Leather Sellers' Company Technical College.

C. H. Marrs, '02, is designing engineer for the Riter-Conley Mfg. Co., at Pittsburg, Pa.

D. W. Marrs, '06, is also with the Riter-Conley Mfg. Co.

W. A. Maxwell, '06, is with the Canadian Bridge Co., Walkerville, Ont.

D. D. McAlpine, '09, is with the General Electric Co. at Pittsfield, Mass.

A. S. McCordick is with the City Electrical Department, Toronto.

F. H. McKechnie is employed on construction with the National Transcontinental Railway, Cochrane, Ont.

H. L. McKinnon, '95, is chief engineer of the C. O. Bartlett & Snow Co., Cleveland, Ohio.

K. McQuarrie, '07, is assistant engineer on Maintenance of Way, Vancouver Division of the C. P. R.

H. G. McVean is at Moose Jaw, Sask.

L. H. Miller, '00, is chief sales agent of Bethlehem Steel Co. for Ohio and Michigan.

E. D. Monk, '08, is assistant chief of Testing Department, General Electric Co., at Pittsfield, Mass.

J. E. A. Moore, '91, is a consulting and contracting engineer at Cleveland, Ohio, specializing on the design and superintendence of manufacturing and power plants.

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APPLIED SCIENCE

INCORPORATED WITH

Transactions of the University of Toronto Engineering Society

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO.

Published monthly during the College year by the University of Toronto Engineering Society

Editorial

The Fourth Estate

A time there was when the profession of engineering journalism did not exist. The intelligent application of scientific principles to the arts of construction was not known. There was no engineering literature and no readers to demand it because there were no trained engineers. The technical man is a product of recent generations and with the technical man has come the technical journal.

The work of the engineering journalist is educational; he puts before the engineer the very latest professional knowledge—what has been evolved through experiment and what has been deduced from analysis. Since, then, he serves his constituency in this especial way, by what standards should his work be measured? Since he must be alive to the problems of the day, he must be alert. He must read extensively—it is assumed that

he knows how. If his reading be extensive, it will be reflected in his work. If not, the lack of it will be equally apparent. Since he must discriminate between the valuable and the worthless; between the purely academic and the practical; between what has a commercial value and what has not; he must be judicial. Since he must on occasion, expose the methods of the knave and the charlatan, he must know something of the devious ways of a perverse business world. A clergyman once asked a lad if he ever swore. The boy's answer, "No, but I know all the words," expresses an attitude toward that section of humanity that lives by its wits, which it is desirable that the journalist who feels the responsibility of his position should maintain. Finally he should know the latest in theory, the best in field practice and should possess a facile pen.

This issue of Applied Science contains eight articles from the pens of graduates, most of whom make technical journalism a profession and with the rest of whom it is a pastime, engineering *per se* being their serious vocation. The variety of subjects treated, the facility of expression and the evidence that the writers are alive to present day problems will be apparent to our readers. That Canada is a growing country is evidenced by the fact that she supports such a large number of really superior technical publications.

On the aggressive and alert technical journalist, the demands are heavy. The position is not easily filled because the qualifications are high, but his field is large and his constituency a growing one. The work of the engineer in Canada during the next generation will be of a magnitude scarcely comprehensible. The development will be on a scale at which few have dared to guess. The engineering journalist will have a heavy responsibility and a great work, but his opportunities will be large and his returns commensurate with his qualifications.

P. G.

F. H. Moody, B.A.Sc., '09, has been appointed Associate Editor of Canadian Machinery.

M. H. Baker, B.A.Sc., '06, has been appointed city engineer of St. Thomas, Ont.

W. K. Greenwood, for many years associated with Willis Chipman, C.E., has received the appointment of town engineer of Orillia, Ont.

A. J. Latornell, B.A.Sc., '03, has been appointed city engineer for Edmonton, Alta., at a salary of $3,600 per year. Mr. Latornell held this position temporarily for some time but this has now been made permanent.

J. M. Wilson, '07, has been appointed city engineer for the city of Moose Jaw.

V. G. Marani has been appointed building inspector for the city of Cleveland.

OUR CONTRIBUTORS.

Dean Galbraith, who contributes "The Elastic Arch" in this issue, is too well known to require any introduction to the readers of Applied Science. As his biography has appeared previously it need not be repeated on this occasion.

Geo. S. Hodgins, the contributor of "Coal and the Locomotive, was one of the School of Practical Science's first students. At all times his tastes and bent were literary, with the mechanical always striving for the leadership; so he compromised by going into technical journalism. Mr. Hodgins has always been connected directly or indirectly with locomotives. For three years after leaving college, in 1881, he was connected with the Canadian Locomotive and Engine Co. at Kingston, Ont. In 1884 he entered the employ of the locomotive department of the Canadian Pacific Railway, remaining with this company for fourteen years with several promotions. In 1898 he returned to the reorganized Canadian Locomotive Works as mechanical engineer. In 1900 he became one of the associate editors of the Railroad Gazette and Railroad Digest. In 1902 he joined the staff of Railway and Locomotive Engineering as associate, continuing in this capacity till 1908, when he became Managing Editor.

Mr. Hodgins is now 49 years old. He is a member of the American Society of Mechanical Engineers and Associate Member, American Railway Master Mechanics' Association.

Walter J. Francis, B.A.Sc., the author of "Engineering in Canada," an excellent article appearing in this issue of Applied Science, is a distinguished alumnus of the School of Practical Science of the class of '93 who at the present time is carrying on a large practice as consulting engineer in Montreal. Our readers will remember an address on "Personality, Character and Technical Training in the Work of the Engineer," given by Mr. Francis before the Engineering Society at its October meeting last fall. As designer for the Central Bridge and Engineering Co. during the middle nineties; subsequently, as division engineer and later engineer of lift locks for the Trent Canal; as superintendent of construction for the West Kootenay Power and Light Company's 32,000 h.p. hydro-electric installation at Nelson, B.C., in 1907; as chief engineer and assistant manager of the Dominion Engineering and Construction Co. of Montreal and as engineer of many works of magnitude which have come under his direction in his private practice since that time, Mr. Francis has in the past sixteen years come face to face with almost every type of engineering problem. His work at the present time is quite as varied. Arbitrations, law suits, consultations on heavy engineering work, reports and betterments, in addition to design and construction are the things in which the public regards Mr. Francis as a specialist. As a contributor

to the technical press he is well known. As an illustration, it may be mentioned that he has been retained to do all the Canadian writing for "The Engineer," London, England, probably the finest engineering magazine in the English language. He is a member of the Council of the Canadian Society of Civil Engineers and a member of the American Society of Civil Engineers. During the past year Mr. Francis has delivered a number of public addresses, among them being one on "Reinforced Concrete for Architectural Purposes," given before the Ontario Association of Architects; one on "Field Made Concrete" before the Canadian Cement and Concrete Association; one on "The Quebec Bridge," before the University of New Brunswick Engineering Society, and another on the same subject before the Engineers' Club of Edmonton. Mr. Francis is an enthusiast in his work, ingenious and resourceful, and those who know his abilities and his capacity for arduous work and for painstaking effort, know that his work is only beginning.

E. A. James, B.A.Sc., the managing editor of the Canadian Engineer, has only been connected with journalism for a little over two years, but in that time he has taken what used to be a trade monthly, and developed it into a real engineering weekly, a paper now not only a credit to the publishers but to the country. It is rapidly growing in scope to be a truly national journal representing engineering and engineering progress from ocean to ocean.

Mr. James has always taken a prominent part in "School" work. In 1905 he was president of the Engineering Society, and a few years later he was elected to the University Senate as one of the representatives of the graduates in Engineering. He was elected an Associate Member of the Canadian Society of Civil Engineers in 1907. Before taking up his editorial work he had considerable practical engineering experience in Ontario, Manitoba and Alberta. He was a resident engineer on construction of the C. P. R. Sudbury line when he assumed his present position.

C. M. Canniff, B.A.Sc. Screened behind the signature of C. E. Easy, C.E. Mr. Canniff has been a frequent contributor to Applied Science. Most of our readers will remember his "Thrice Told Proverbs," "Ye Lady Engineer" and "India Ink." In fact he has established himself so securely among our writers that any special issue of Applied Science such as this would not be complete without him. Mr. Canniff is one of the earlier graduates of the School of Practical Science, having completed his course in civil engineering in 1888. His first position was as assistant to the late Alan Macdougall, C.E., later he accompanied Mr. Macdougall to the City Hall upon that gentleman's appointment as Assistant City Engineer for Toronto. Upon the institution of the City Surveyor's office, Mr. Canniff succeeded to the position of chief assistant, remaining there until 1898 when he

resigned to accept a post as engineer for the Expanded Metal and Fireproofing Co. of Toronto. Since that date he has been continuously identified with reinforced concrete construction. In 1908 he was appointed chief engineer of this company, a position he now holds. With H. J. Chewett, B.A.Sc., in 1897 Mr. Canniff collaborated in the authorship of the "Pocket Manual of Mining," which was well received. Mr. Canniff has always taken a deep interest in literary work. In his undergraduate days he was an editor of Varsity. He has always been a prominent club man, and is at present, president of the Engineers' Club of Toronto, and a member of the Canadian Society of Civil Engineers. He took an active interest in the Engineering Club of Ontario, which has recently been organized.

J. C. Armer, B.A.Sc., editor Canadian Manufacturer, graduated from the School of Practical Science in 1906. He received his High School education in Chesley, Ont. He was in the publishing business before entering the then School of Practical Science, with the MacLean Publishing Co. He took the mechanical and electrical course, at the same time continuing his connection with the MacLean Publishing Co. as associate editor of Canadian Machinery. In this latter capacity he spent most of his summer months in going from one manufacturing plant to another, gathering information on machine shop methods of interest and value. He was also at one time employed on machine shop work with the Grand Trunk Railway.

In 1907 Mr. Armer was appointed editor of Canadian Machinery. In the fall of 1908 he resigned this position to become editor of the Canadian Manufacturer, with a financial interest in the publication.

A. E. Uren, B.A.Sc., who contributes "The Action of Frost on Hydraulic Cement" in this issue, received his public and high school education at Ingersoll, Ontario, and entered the School with the class of 1905, taking the course of mechanical and electrical engineering. He followed his profession for some years in Winnipeg and the West. For the last three years, however, he has been identified with the Canadian Engineer and the Canadian Cement and Concrete Review, at the present time holding the position of managing editor of the latter publication.

C. C. Bothwell, associate editor of the Canadian Electrical News, was a member of the class of '07. He has had considerable practical experience in power house and development work. He joined the staff of the Electrical News last year and is now the representative in Eastern Canada.

K. A. MacKenzie, B.A.Sc., has been associated with Applied Science since its inception three years ago, as its managing editor. He was a member of the class of '06.

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